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Soil Survey

Kings County California

By
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UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Administration, Bureau of
Plant Industry, Soils, and Agricultural
Engineering
In cooperation with the
UNIVERSITY OF CALIFORNIA AGRICULTURAL EXPERIMENTAL STATION

HOW TO USE THE SOIL SURVEY REPORT

SOIL SURVEYS provide a foundation for all land use programs. The report on each survey and the map that accompanies the report present information both general and specific about the soils, the crops, and the agriculture of the area surveyed. The individual reader may be interested in the whole report or only in some particular part. Ordinarily he will be able to obtain the information he needs without reading the whole. Prepared for both general and detailed use, the report is designed to meet the needs of a wide variety of readers of three general groups: (1) Those interested in the area as a whole; (2) those interested in specific parts of it; and (3) students and teachers of soil science and related agricultural subjects. Attempt has been made to meet the needs of all three groups by making the report comprehensive for purposes of reference.

Readers interested in the area as a whole include those concerned with general land use planning—the placement and development of highways, power lines, urban sites, industries, community cooperatives, resettlement projects, and areas for private or public forests, recreation, and wildlife management. The following sections are intended for such users: (1) General Nature of the County, in which physiography, relief, drainage, climate, water supply, vegetation, history, population, industries, transportation, markets, and cultural developments are discussed; (2) Agriculture, in which a brief history of the agriculture is given and the present agriculture described; (3) Soil ratings, in which the soils are rated according to their potential suitability for the production of crops.

Readers interested chiefly in specific areas—such as some particular locality, farm, or field—include farmers, agricultural technicians interested in planning operations in communities or on individual farms, and real estate agents, land appraisers, prospective purchasers and tenants, and farm loan agencies. The reader's first step is to locate on the map the tract with which he is concerned. The second is to identify the soils on the tract by locating in the legend on the margin of the map the symbols and colors that represent them. The third step is to locate in the table of contents in the section on Soils the page where each type is described in detail and information given as to its suitability for use and its relations to crops and agriculture.

Students and teachers of soil science and allied subjects, including crop production, forestry, animal husbandry, economics, rural sociology, geography, and geology, will find their special interest in the section on Morphology and Genesis of Soils. They will also find useful information in the section on Soils, in which is presented the general scheme of classification of the soils of the area and a detailed discussion of each type. For those not already familiar with the classification and mapping of soils, these subjects are discussed under Soil Survey Methods and Definitions. Teachers of other subjects will find the sections on General Nature of the County, Agriculture, Laboratory Studies, and the first part of the section on Soils of particular value in determining the relations between their special subjects and the soils of the area.

This publication on the soil survey of Kings County, Calif., is a cooperative contribution from the—

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SOIL SURVEY OF KINGS COUNTY, CALIFORNIA

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United States Department of Agriculture in cooperation with the University of California Agricultural Experiment Station

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[1] The field work for this survey was done while the Division was a part of the Bureau of Chemistry and Soils.

THE gold rush of 1849 was the main factor in bringing settlers to what is now Kings County. At first, cattle and sheep raising were the principal agricultural pursuits, but wheat soon became the major agricultural product. The introduction of alfalfa in the latter part of the nineteenth century stimulated dairying and helped to form a more diversified agriculture, which included fruits and cotton. At present dairying is one of the most important enterprises. The county was formed from the western part of Tulare County on March 11, 1893, with Hanford as the county seat. The discovery of oil in the Kettleman Hills added greatly to the importance and wealth of the county. The oil industry is concerned chiefly with the production of raw material for the refineries. Cotton ginning, fruit packing, and milk processing are the most important industries concerned with agriculture. Other industries are a skim-milk and buttermilk condensing plant, two creameries, two fruit-canning establishments, a fruit drying and packing plant, several establishments where fruit is graded and boxed, a tallow factory, a slaughter house, and a winery. To provide a basis for the best agricultural uses of the land a cooperative soil survey was begun in 1938 by the United States Department of Agriculture and the University of California Agricultural Experiment Station. The essential features may be summarized as follows.

SUMMARY

Kings County occupies 1,380 square miles just below the center of the San Joaquin Valley. Its southwestern corner extends into the Coast Range Mountains, and its eastern boundary is about 20 miles east of the axis of the San Joaquin Valley, which passes through the county in a northwest-southeast direction. Based on relief there are three broad and almost equal divisions of the county: (1) The Kings River alluvial fan in the northeast third; (2) Tulare Lake Basin in the southeast third; and (3) the Kettleman Hills and Diablo Mountains with their small valleys and alluvial fans in the southwest third.

The climate is semiarid with hot, dry summers and mild, moist, foggy winters. The seasonal rainfall is less than 10 inches, and the general climate is rather uniform.

The western part of the county is almost entirely uncultivated owing to the absence of water for irrigation, but in most places it furnishes good grazing for cattle and sheep. *Atriplex*, snakeweed, California sage, and other low-growing shrubs are common, and in the mountains at higher elevations blue oak and scrub pine are found. The southeastern part of the county is made up of the Tulare Lake Basin, which is farmed when dry. This is the extensive agricultural area of the county where the production of grain, cotton, and, to a lesser degree, sugar beets is carried on in large tracts. This area is well known for the quantity and quality of the grain it produces. Intensive and diversified agriculture is found on the Kings River alluvial fan. Here apricots, peaches, and grapes are produced. Alfalfa is also grown extensively and on its production depends the large dairy enterprise of the county. Here, too, cotton yields well, but the size of the fields contrasts sharply with those in the lake-bottom area by being small—about 15 to 60 acres in size.

Grangeville and Dinuba light-brown soils and the dark-gray Foster soils are representative of the recent alluvial fans and flood plains.

These deep, loose, and permeable soils are well adapted to intensive agricultural practices. The high water table, however, interferes with development of deep-rooted plants and causes a slow rise of alkali from the subsoils into the surface soils. Most areas of the Panoche soils, another member of this group, are not cultivated, because of the absence of irrigation water. The soils of the valley basin are represented by the Hacienda, Merced, Rossi, Temple, and Tulare series. The Merced and the Temple and many areas of the Tulare soils are well suited to grain or cotton. Many of the other soils are used only for grazing, because of alkali accumulations, lack of water for irrigation, or rough broken relief.

Differences in color, parent material, soil profile, and drainage conditions have given rise to 20 soil series with 42 soil types, 8 phases, 1 complex, and 2 miscellaneous land types.

Much of the arable land was brought into intensive agricultural production by the reclamation of swamp and overflow lands and by the construction of irrigation systems. Surface irrigation and sub-irrigation are both practiced on the Kings River fan. Irrigation canals follow the low ridges of higher ground. Gravity water for irrigation is supplemented by water pumped from wells.

Alkali refers to all soluble mineral salts that as a result of poor drainage and surface evaporation accumulate in the soil in sufficient concentration to injure plant growth. The saline soils in this area are divided into two groups—black alkali and white alkali—but local usage makes no distinction between them and designate both as alkali soils.

The soils are placed in six grades, according to potential suitability for the production of crops; and in five groups, on the basis of land use and profile characteristics. The intrazonal and azonal soils represent the great soil groups in the area. There are no zonal soils. All but three of the soil series belong to the intrazonal group.

GENERAL NATURE OF THE COUNTY

LOCATION AND EXTENT

Kings County lies slightly south of the center of the San Joaquin Valley, which together with the Sacramento Valley constitutes the great interior valley of California (fig. 1). Hanford, the county seat and largest town, is 185 miles south of Sacramento, 185 miles southeast of San Francisco and 175 miles north of Los Angeles. Sequoia and Yosemite National Parks lie 63 miles east and 94 miles north, respectively.

The total area of Kings County is 1,380 square miles, or 883,200 acres. Parts of the county have been covered by three earlier soil surveys; the most detailed one was a survey of the Hanford area made in 1901 (*20*).[2] It was one of the first soil surveys made in California by the United States Department of Agriculture. The other two surveys were reconnaissance soil surveys of the Middle San Joaquin Valley made in 1916 (*13*) and the Upper San Joaquin Valley made in 1917 (*23*). Each of the three surveys covers a part of Kings County. The surveyed Fresno area (*29*) adjoins the county on the

[2] Italic numbers in parentheses refer to Literature Cited, p. 104.

FIGURE 1.—Location of Kings County in California.

north, and the Visalia (*27*) and Pixley areas (*28*) on the northeast and east. A part of the Wasco area (*2*) adjoins the county at the southeast corner, and the Paso Robles area (*10*) adjoins the county on the southwest.

PHYSIOGRAPHY, RELIEF, AND DRAINAGE

A clear and vivid description of the physiography together with the geology of the region is given by Bailey (*3, pp. 45–48*), and a general idea of its position is obtained from figure 1. Bailey states:

The valley is a level-floored depression more than 500 miles long and from twenty to fifty miles wide. It includes both the San Joaquin and Sacramento valleys and has an area of 18,000 square miles * * * It is a vast plain without rock outcrop or terrace; with sluggish streams; and even tidal slough at one point.

It is canoe shaped, with only a notch in the rim to let the water spill out.

Along the sides are uplands of sloping plains or alluvial fans reaching to the foothills; but the elevation of the floor varies from tide level at the notch in the rim at Carquinez Straits to 100 feet at Marysville Buttes and 800 at Redding; while the elevation at the south is 420 feet at Bakersfield.

The Great Valley is as well fenced in as a great ranch. On the east rise the Sierras with elevation from 12,000 to 14,000; while to the west the Coast Range forms a series of parallel ridges of moderate height; inclosing many narrow valleys, like the Salinas Valley. At the north Mt. Shasta and the Cascade Range form the inclosing wall; while the south end is closed by the Coast Range joining the Sierras. * * *

The drainage into the valley is mainly from the Sierras on the east side; * * * The streams from the Sierras have large watersheds, long courses and

flow from the highest range in the United States where the rainfall is heavy and the snows are deep.

The streams from the Coast Range are either not permanent or small and erratic and of much less importance than those from the east side. * * *

This valley is a great structural trough—tectonic trough—in which a series of sediments have accumulated from the earliest Cretaceous times to the present. * * *

The valley was a marine sea during the Eocene and up to the Middle Miocene, when the Coast Ranges were born. During the rest of its history it was a great bay, or series of lakes, with salt water filling some; while others were brackish or fresh, as shown by the fossils in the sediment.

There is little diversity in the physical aspect of the Great Valley, the differences between the north and south being largely climatic.

The most striking features of the valley are the alluvial fans and aprons which border the edges. The apex of a fan is at the mouth of a canyon, for the fan is simply the material dropped by the stream when it emerges from the canyon.

Some idea of the depth of the sediments filling the valley is obtained from Reed (*24, p. 19*):

The deepest well [oil] so far drilled (1933) in the area is 9,700 feet deep. It is located near the center of the valley, south of Tulare Lake, and penetrated no rocks older than uppermost Miocene. The sediments are monotonously uniform from top to bottom. Non-marine at first, they become alternately marine and non-marine from 2,500 to 4,000 feet and marine from that depth to the bottom of the hole * * * Estimates based on geophysical data have been made of the maximum thickness of rocks above the basement in the central and western parts of the valley. They indicate that the sedimentary blanket, possibly including some Franciscan rocks, is approximately 25,000 feet thick a short distance east of the outermost foothills along the west edge of the valley * * *. The gentle structure suggests that the basement, like the Sierra Nevada, is little fractured; it suggests in fact, that the basement is a continuation of the Sierra Nevada.

The general relief of the county is of three distinct kinds: (1) Depressional and lacustrine, (2) gently sloping confluent alluvial fans, and (3) hilly mountainous areas. The axis of the San Joaquin Valley enters the county in the northwest corner, continues southeastward for 15 miles, and then abruptly flares open to form Tulare Lake. This was originally one of the largest lakes in California and occupied the entire southeastern third of Kings County. It has been greatly restricted, however, by dikes and diversion of water for irrigation, and in some recent years it has gone dry. The northeastern third consists of the Kings River fan, a huge, almost flat mass of alluvial material deposited by the Kings River. Its vast surface is much dissected and cut by shallow meandering sloughs and creeks. West of the valley axis the brown grass-covered, much-dissected, and eroded Kettleman Hills extend in a northwest-southeast direction. Their highest point at La Cima, but not the highest point in the county, has an elevation of 1,366 feet,[3] whereas the lowest point, 178 feet, occurs in Tulare Lake bottom only a few miles to the northeast of La Cima. The Kettleman Plain, a long narrow valley, separates the Kettleman Hills from the Kreyenhagen Hills, the low foothills at the base of the Diablo Range. Reef Ridge, a former horizontal sedimentary rock layer has been upturned and forms the east side of the Diablo Range, a segment of the inclusive Coast Range Mountains. The highest point, nearly 3,473 feet above sea level, is on Table Mountain near the Kings Mine. McLure Valley (Sunflower Valley), a pocket 6 miles east of

[3]All elevations are taken from the topographic maps prepared by the U. S. Geological Survey, Dept. of the Interior.

the southwest corner, has an elevation of about 700 feet. The elevation of the Kettleman Plain ranges between 420 and 775 feet. Hanford has an elevation of 245 to 250 feet, and the highest point on the Kings River fan is about 295 feet.

CLIMATE

The climate of Kings County is distinctly semiarid, the year being divided roughly into a wet and a dry season. Spring and fall are not distinct seasons but more nearly represent mild transitions between summer and winter. The climate is fairly representative of the San Joaquin Valley, where oceanic and continental influences are excluded by the high protecting wall of mountains that enclose the valley on the east, south, and west. Summers are hot and dry, the hotter days having a temperature of 100° to 112° F., interspersed with temperatures of 90° to 100°. July and August are the two hottest months. Evaporation is rapid, and the summer temperatures are ideal for drying fruits. The spring months have a mean temperature of 60° to 62°, whereas the fall months have a mean temperature of 62° to 66°. December and January are the coldest months, with a mean temperature of 45.3° for each at Hanford. The damp unpleasant days of winter are not continuous but are interspersed with mild clear sunny periods. Minor variations of temperature occur within the county. In general west of the valley floor it is hotter than at Hanford and in the lake-bottom areas.

The average length of the frost-free season at Hanford is 257 days, whereas at Dudley, situated in the foothills west of the valley floor, it is 251 days. Frost has been recorded at Hanford as early as October 11 and as late as May 26. In general, frost damage will come earlier in areas of lowest altitude, as in the Tulare Lake Basin. Damage from frost in fall is limited to late-planted cotton that has not yet completely ripened or to sorghums being used for pasture. In the latter case frost causes the formation of prussic acid in the sorghums, and this proves fatal when fed to livestock. The new fruit crop may be damaged by frost in spring, and especially so if it follows an earlier prolonged warm period. Some orchard heating is done, but the practice is not general.

Rain is practically unknown in June, July, and August, and normally only light showers occur in May and September. The greatest precipitation is from December to April. Normally, rains occur as light prolonged showers separated by clear days. Cloudbursts are rare, but they do occur in the mountainous southwestern part. Snow and hail are practically unknown. The total rainfall is less than 10 inches, with an average precipitation of 6.38 inches at Dudley. It is probable that the mountainous area receives considerable more moisture but there are no records to verify this.

No special crops are produced in Kings County because of the climate other than the crops common to the general region, including cotton, grapes for raisins and wine, and fruits for drying. Records of the United States Weather Bureau stations at Hanford and Dudley, as shown in table 1, present data typical of climatic conditions throughout the county.

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation at certain stations in Kings County, Calif.*[1]

[Hanford, elevation, 249 feet]

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total for the driest year	Total for the wettest year
	°F.	°F.	°F.	*Inches*	*Inches*	*Inches*
December	45.3	80	18	1.06	0.97	3.43
January	45.3	95	14	1.69	.39	1.59
February	50.7	94	18	1.36	.95	1.92
Winter	47.1	95	14	4.11	2.31	6.94
March	54.8	95	23	1.59	1.01	4.05
April	60.8	100	20	.60	.15	.62
May	67.2	105	30	.40	.10	2.06
Spring	60.9	105	20	2.59	1.26	6.73
June	75.4	114	36	.11	0	.02
July	80.7	115	44	0	0	0
August	78.7	111	40	.01	0	0
Summer	78.3	115	36	.12	0	.02
September	72.3	109	35	.36	.22	0
October	63.0	98	28	.28	.03	0
November	53.0	94	20	.75	(2)	.12
Fall	62.8	109	20	1.39	.25	.12
Year	62.3	[3] 115	[4] 14	8.21	[5] 3.82	[6] 13.81

[Dudley, elevation, 595 feet]

Month	Mean	Absolute maximum	Absolute minimum	Mean	Total for the driest year	Total for the wettest year
December	47.7	84	18	0.74	0.07	1.04
January	46.5	85	16	1.25	.44	.30
February	52.5	87	20	1.27	.81	6.26
Winter	48.9	87	16	3.26	1.32	7.60
March	56.0	98	25	1.20	.38	2.65
April	61.7	98	30	.42	.20	.07
May	68.7	106	34	.34	0	(2)
Spring	62.1	106	25	1.96	.58	2.72
June	77.4	111	38	.04	.02	0
July	85.4	118	51	.01	0	0
August	84.2	118	49	.04	0	0
Summer	82.3	118	38	.09	.02	0
September	75.6	111	42	.13	.15	.25
October	66.3	108	35	.36	0	.18
November	56.2	90	17	.58	0	1.03
Fall	66.0	111	17	1.07	.15	1.46
Year	64.8	[7] 118	[8] 16	6.38	[9] 2.07	[10] 11.78

[1] Records from the U. S. Weather Bureau.
[2] Trace.
[3] July 1931.
[4] January 1916.
[5] In 1919.
[6] In 1906.
[7] July 1926, August 1920.
[8] January 1913.
[9] In 1929.
[10] In 1918.

Winds for the most part blow down the axis of the valley from a northwest direction. They attain their greatest velocities during spring and early summer and blow stronger on the west side of the valley, where no trees impede their progress. At times they sweep across Tulare Lake with considerable force. The sand barrier at the

southern edge of the lake has thus been piled up. Heavy fogs are common during December and to about January 15. For the most part they blanket the ground till almost noon, when they disperse and the day is clear, but sometime during this period a succession of completely foggy days with no sunshine is to be expected. The fog may remain from 3 to 6 weeks but is dispersed by the winter rains and does not gather so thickly again.

With the exception of an occasional stormy day in winter, general routine farm work is not interrupted. The climate is never so severe as to make shelters a necessity for range livestock, although a few of the dairy farms have barns to shelter the herd.

VEGETATION

In general native vegetation consists largely of grasses and shrubs common to a semiarid region. Though some of the plants prefer specific soils or certain alkali [4] conditions, the large majority of them will grow in most parts of the county.

The county may be divided into three physiographic and vegetative regions: The lake bed and poorly drained areas, the Kings River fan comprising the northeastern third, and the area west of the valley axis. Certain plants have a preference or a tolerance for strong accumulations of salts or alkali conditions, and this relation is carefully observed in determining and mapping the different conditions of alkali accumulation found in the field. It should be remembered, however, that most of these plants will also grow on soils having lower salt content, and their presence is not always indicative of a severe alkali concentration. Common saltgrass, which is an example of this, is the most common grass of the poorly drained areas and of soils of the old lake bed, being most abundant on the Fresno, Pond, Traver, and Hacienda soils, but it also grows on the Grangeville and Foster soils. It is a tough, wiry grass and is eaten by cattle when other feed is absent. The bromegrasses are represented to some degree on these soils, and they have good grazing value. The Tulare clay, clay loam, and loam soils originally supported a dense cover of the common tule, but these, together with the wire rush, are now found only in irrigation canals. Alkali weed, a low-growing grayish-green plant, is now a field pest on these soils. It is generally found in circular areas of 1 acre or less, and all other plants are excluded from this area. Alkali heath is usually limited to the Hacienda, Tulare, Merced, and Rossi soils. Foxtail chess, meadow barley, and mouse barley usually line the canal banks in all parts of the county. The most conspicuous alkali plant is the pickleweed, or inkweed, sometimes called iodine bush. It is found on all areas of strong salt accumulation east of the valley floor and is a more accurate indicator of severe alkali conditions than saltgrass. Sea blite is also confined to areas of strong alkali. California greasewood is a shrub growing on the Hacienda soils in the southeastern part, in a narrow belt west of Stratford, where the Tulare and Lethent soils join, and to some extent on the Chino and Rossi soils from Stratford east to Cross Creek. It has no value and usually indi-

[4] Chemically the term "alkali" is confined to such salts as sodium carbonate (black alkali), which give an alkaline reaction in solution, but it is used in this report in the wider agricultural sense to include such soluble salts of neutral reaction as sodium chloride, sodium sulfate, calcium chloride, and magnesium chloride, which may become injurious to plants where sufficiently concentrated.

cates the strongest of alkali conditions. Other shrubs largely of the genus *Atriplex* are scattered throughout.

The river and sloughways common to the Kings River fan are lined with willows and cottonwood. Giant valley oaks are common north of Hanford and Lemoore. Spikeweed, although the most common of all weeds in pastures and fence rows of the Kings River fan, has little grazing value, because of its pungent odor and thornlike vegetation. It frequently crowds out the more desirable grazing plants and will grow under a wide range of alkali conditions, and though usually found on the Grangeville, Foster, and Traver soils, it will grow on most of the soils east of the axis of the valley. The well established Bermuda grass and Johnson grass are the most serious plant pests. They limit the life of alfalfa fields to 4 years, check the growth of cotton, and demand constant attention in orchards and vineyards. Bermuda grass will tolerate a moderate quantity of alkali, whereas Johnson grass prefers soils free of salts. Both grasses occur chiefly on the Grangeville and Foster soils. The infestation of the dreaded puncturevine is light, and attempts are being made to control it. Wild sunflowers cause most trouble along canal banks, where their growth is very rank. A dense growth of cockleburs in the sloughway pastures west and north of Lemoore limits the grazing value of these areas late in summer and in fall.

The third of the county lying west of the valley trough is the most important grazing area, and here the native vegetation has been little disturbed. The Lethent soils are high in alkali and support only a sparse cover of the bromegrasses. *Atriplex* (saltbush) is common and withstands large quantities of salts. This saltbush is also common on the Kettleman soils and affords good spring browsing. Formerly these hills were largely covered with *Atriplex*, but fires have greatly reduced its extent. The poisonous locoweed is increasing rapidly, and as these soils are used almost exclusively for sheep grazing the problem is becoming serious. The Kettleman soils are thinly covered with grasses, and here the snakeweed, a low growing green-stemmed shrub that interrupts the grass cover, is found. This shrub is limited to the Kettleman soils and the rough mountainous land. The mountainous areas are spotted with hardy oaks, of which the blue oak is a common member. Junipers occur along Avenal Creek near and above the 1,200-foot level, and scrub pines come in at about 1,800 feet.

In addition to the trees and grasses, however, a wide variety of brush and shrubs occur. Specimens collected in the mountains east of Stoker Canyon in the southwestern part and believed to be fairly representative of this brush cover include goldenfleece, California sagebrush, black sage, flattop Indian tobacco, and snakeweed. The grazing value of this west-side region, however, depends upon certain grasses and associated plants common to all the soils. Of these, alfileria is by far the most important and its abundance largely determines the quality of the grazing each year. It is a spring and summer feed and is ruined by the first fall rains. Foxtail is of second importance as a spring and summer feed, but it is most valuable in fall as a carry-over feed after the fall rains have ruined the other plants. Bur-clover makes an excellent feed when plentiful, but it cannot always be depended on because of a fluctuation in its life cycle habits caused by moisture conditions. Peppergrass is an excellent early feed but loses its value with its seed late in spring. Blow-

wives and soft cheat grow in abundance in the foothills west of Avenal. The genus *Bromus* is represented by a number of plants in this region all of which are well suited to grazing. Three weeds that have no grazing value but are abundant are tumbleweed, mullein, and fiddle-neck. A good cross sectional view of the native vegetation of the county is shown in figure 2.

LIST OF PLANTS IN KINGS COUNTY, CALIF.

Scientific name	*Common name*
Achyrachaena mollis Schauer	Blowwives.
Adenostoma fasciculatum Hook. and Arn	California greasewood, iodine bush.
Allenrolfea occidentalis (S. Wats.) O. Ktze	Pickleweed, inkweed.
Amaranthus graecizans L	Tumbleweed.
Aplopappus arborescens (Gray) Hall	Goldenfleece.
Artemisia californica Less	California sagebrush.
Astragalus sp	Locoweed.
Atriplex sp	Saltbush.
Bromus mollis L	Soft cheat.
B. rubens L	Foxtail chess.
Centromadia pungens (Hook. and Arn.) Greene	Spikeweed.
Cressa truxillensis H. B. K	Alkali weed.
Crithmum maritimum L	Samphire.
Cynodon dactylon (L.) Pers	Bermuda grass.
Distichlis stricta (Torr.) Rydb	Saltgrass.
Eremocarpus setigerus (Hook.) Benth	Turkeymullein.
Eriogonum fasciculatum Benth	Flattop Indian tobacco.
Erodium cicutarium (L.) L'Her	Alfileria.
Frankenia grandifolia Cham. and Schlecht	Alkali heath.
Gutierrezia californica (DC.) Torr. and Gray	Snakeweed.
Helianthus californicus DC	Wild sunflower.
Hordeum murinum L	Mouse barley.
H. nodosum L	Meadow barley.
Juncus balticus Willd	Wire rush.
Juniperus sp	Juniper.
Lepidium nitidum Nutt	Peppergrass.
(*Medicago arabica hispida*) = *Medicago hispida* Gaertn.	Bur-clover.
Phacelia tanacetifolia Benth	Fiddle-neck.
Pinus contorta Loud	Scrub pine.
Quercus douglasii Hook. and Arn	Blue oak.
Salvia mellifera Greene	Black sage.
Scirpus lacustris L	Common tule.
Sorghum halepense (L.) Pers	Johnson grass.
Suaeda californica S. Wats	Sea blite.
Tribulus terrestris L	Puncturevine.
Xanthium sp	Cocklebur.

ORGANIZATION AND POPULATION

Comandante Tagus, a soldier from one of the Spanish coastal settlements, is said to have been one of the first white men to enter the part of the San Joaquin Valley that now comprises Kings County. In 1773 he discovered a large lake which he named Los Tules because of the abundant growth of tules or rushes in and around the large shallow body of water. Subsequently the name changed to Tulare Lake, and although it has been dry for intermittent periods the general region of the old lake is still known as Tulare Lake or Tulare Lake Basin.

At the time of the advent of white men, the San Joaquin Valley abounded in game and was the home of numerous waterfowl. Tulare Lake contained many edible fishes. The shores of the lake were a favorite place for Indian tribes. The Tachi Indians, a subtribe

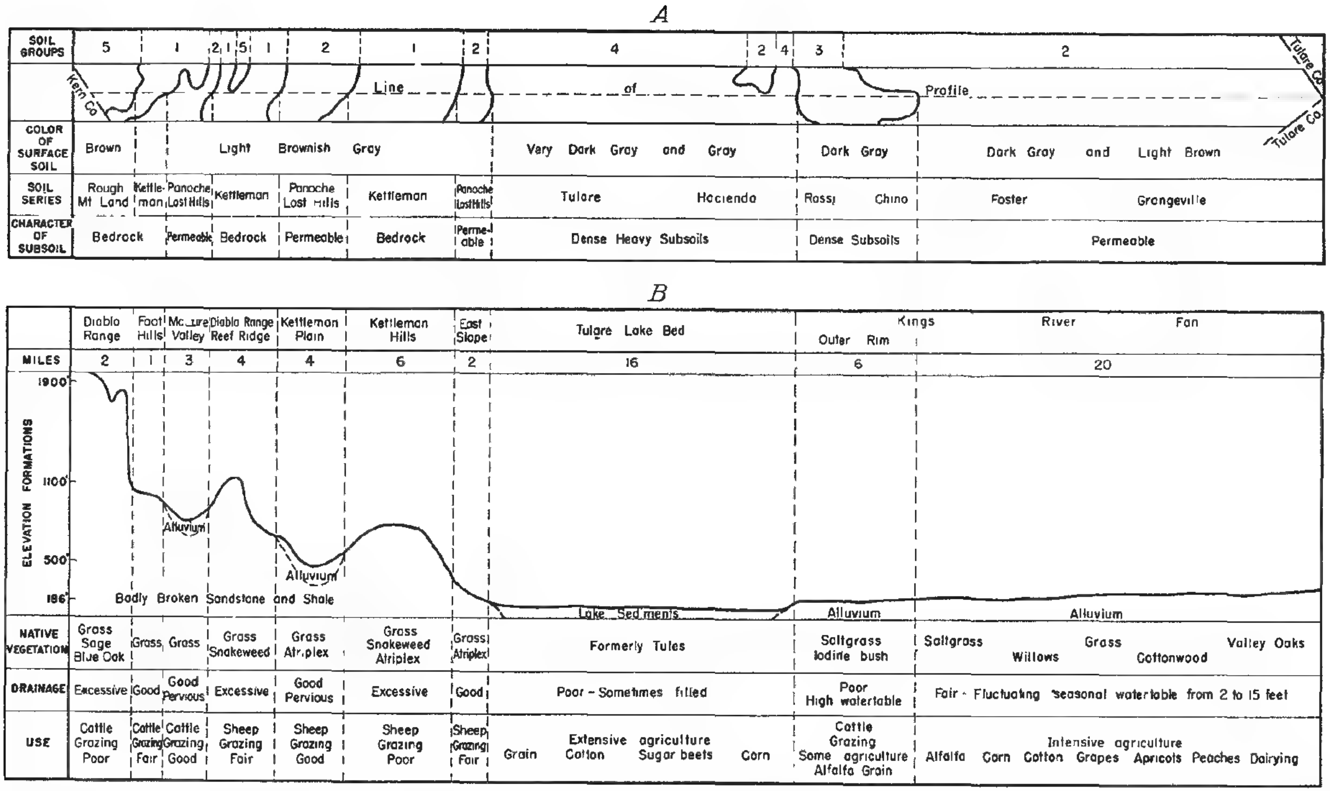

FIGURE 2.—Diagrammatic cross section of Kings County, extending from a point 4 miles east of the southwestern corner to the northeastern corner: *A*, Horizontal section 4 miles wide showing the occurrence of the major soil groups through which the vertical profile in part *B* passes; *B*, relation of the different soil groups to the topography, drainage, parent material, and native vegetation and the agricultural use indicated.

of Yokuts, were particularly associated with Tulare Lake, and it is from this subtribe that the Spanish land grant "Laguna de Tache" received its name. There were a number of other tribes and subtribes in the San Joaquin Valley at this time, and many of them moved from place to place in the valley and mountains as the seasons changed. In summer they stalked deer in the Sierras; in fall they gathered acorns from the oaks along the foothills; and in winter they hunted ducks along the edges of Tulare Lake.

According to tradition, a Spanish exploration party from the Presidio at San Francisco discovered Kings River in 1805 and named it "Rio de Los Santos Reyes," or River of the Holy Kings. Jedediah S. Smith and "Pegleg" Smith, the first white men to enter the San Joaquin Valley overland, entered the region about 1826 and 1830, respectively. Ewing Young and his party are said to have hunted in the vicinity of Tulare Lake in 1831, and in 1841 John C. Fremont made his way up the valley.

The gold rush of 1849 was the main factor in bringing settlers to the San Joaquin Valley and to the area that is now Kings County. Cattle and sheep raising were the main agricultural pursuits at first, but soon wheat became the major agricultural product. After the railroad afforded more rapid transportation irrigated orchards and vineyards became profitable, and with intensive agriculture development the region of Kings County began to assume prominence. The introduction of alfalfa in the latter part of the nineteenth century stimulated dairying and helped to form a more diversified agriculture.

Agitation for the formation of Kings County from the western part of Tulare County began about 1887, and on March 11, 1893, by act of the State Legislature, the new county was created, with Hanford as the county seat. The original area of the county was 1,039 square miles and the population was 7,325. In 1908 a part of Fresno County was annexed. The following figures for growth and present composition and distribution of the population are taken from United States census reports: Total population in 1900, 9,871; 1910, 16,230; 1920, 22,031; 1930, 25,385; and 1940, 35,168. The rural population was 26,934 in 1940, or 76.6 percent. The average density in 1940 was 25.2 persons to the square mile, with a rural density of about 19.3. The unbalanced distribution of the total population is accounted for by the fact that an adequate water supply and suitable soils for intensive agricultural practices lie only in the northern and northeastern parts; and it is in this part that Hanford, the largest town, is located.

Kings County is well supplied with schools. There are about forty [5] elementary school districts, of which five are joint districts with neighboring counties. There are six union high schools of which three are joint schools.

The three largest towns are Hanford, Lemoore, and Corcoran. Hanford, named in honor of J. M. Hanford, an early official of the Southern Pacific Railroad Company, was laid out as a town site in 1877 and became incorporated in 1891. Hanford has had a steady growth in population, from 942 in 1890 to 8,234 in 1940. It is a shipping point for dairy products and fruits. Lemoore, named after Lavern Lee Moore, an early settler and prominent citizen, began its growth with the coming of the railroad in 1877. The population in

[5] KINGS COUNTY CHAMBER OF COMMERCE. THE FACTS ABOUT KINGS COUNTY. 94 pp. Hanford, Calif. 1925. [Processed.]

1910 was 1,000; and in 1940, 1,711. The town was incorporated in 1913 and is a shipping point for dairy products, fruit, and grain. Corcoran, originally a junction of the Santa Fe Railroad with its east side branch, was named after General Corcoran, one of the pioneers of the San Joaquin Valley. Corcoran has had a steady growth in population, from 1,100 in 1920 to 2,092 in 1940. The town was incorporated in 1914 and is a shipping point for grain and cotton. Other shipping points in Kings County are: Avenal, a growing town, principally concerned with the oil industry; Armona, a shipping point for fruits; Stratford, a shipping point for grain; Kettleman City, an oil-industry town; and Hardwick, a fruit-shipping point.

INDUSTRIES AND POWER DISTRIBUTION

The discovery of oil in the Kettleman Hills added greatly to the importance and wealth of Kings County. Drilling for oil began on these hills about 1907,[6] but the wells were for the most part relatively shallow, and oil-bearing strata were not reached. The hills were further prospected, however, by "wildcat" drillers, and in 1924 a small quantity of low-gravity oil was pumped from one of them, but no excitement was created until the Milham Exploration Company's "Elliott No. 1" well, 7,108 feet deep, was brought fully under control November 7, 1928, with a production of 3,670 barrels a day of 60° gravity oil. As other wells soon followed, the towns of Kettleman City on the east side of Kettleman Hills and Avenal on the west side sprang into existence. Today the Kettleman Hills oil field is one of the most important in California, ranking first in 1937 with a production for the year of 29,038,428 barrels. The field is also a large gas producer and is an important link in the pipe-line system that supplies San Francisco and Oakland with natural fuel gas. Hanford and Fresno are also supplied with gas from this field.

The oil industry is concerned chiefly with the production of the raw material for the refineries. Most of the crude oil is pumped through pipes to refineries in the San Francisco Bay region, although there is one small refinery in Hanford, and a few gas plants in the Kettleman Hills. Petroleum is by far the chief mineral resource, but there are indications of deposits of chromite, fuller's earth, gypsum, and quicksilver in the hills and mountains in the southwestern part (7).

Cotton ginning, fruit packing, and milk processing are the most important industries concerned with agriculture. Cotton gins are at Corcoran, Hanford, and Stratford. A cottonseed mill at Corcoran processes cake and oil. Some of the cake is sold throughout the county, and 5,000 to 7,000 head of steers are fattened at Corcoran each year.

The county has two fruit-canning establishments, one in Hanford and one in Armona, but for the last few years only the plant in Armona has been in operation. In 1937 the Armona cannery produced approximately 430,000 cases of canned goods, some of which was spinach grown in Tulare County. The Armona plant does not can fruits grown in Kings County exclusively but receives some shipments from Tulare and Fresno Counties; most of the apricots canned, however, are grown in the county. A fruit drying and packing plant that

[6] BEEBE, J. W. KETTLEMAN HILLS AND DUDLEY RIDGE GAS AREA. Hanford [Calif.] Journal, 46 pp., illus. 1932.

produces between 3,000 and 4,000 tons of dried apricots and peaches annually is located in Hanford. Prunes are generally dried and cleaned in Visalia; raisins are generally processed in Fresno. Several establishments where fruit is graded and boxed are operated in various towns in the fruit-growing sections. A winery about 5 miles northwest of Hanford has an annual capacity of approximately 1,000,000 gallons. In 1937 this plant manufactured 880,066 gallons of fortified sweet wines, using chiefly Muscat of Alexandria grapes from Kings County supplemented by other varieties from this and neighboring counties.

Other agricultural industries are a tallow factory a few miles east of Hanford, a slaughterhouse east of Hanford, and a skim-milk and buttermilk condensing plant in Lemoore, and creameries at Hanford and at Lemoore. An abandoned beet-sugar factory stands in Corcoran that was built in anticipation of a steady local supply of raw material, but it was forced to close down when the curly top disease wiped out the sugar beet crops in 1918 and 1919.

Electric power is supplied to Kings County by the San Joaquin Light and Power Company and the Southern California Edison Company. The former company serves most of the county. Electricity is available to almost every farm, and 1,931 farms use electricity for lighting (1940 census) and as a source of power mainly for well pumps supplying domestic and irrigation water. Both power companies have men and equipment in the field for the purpose of checking the efficiency of motors and pumping apparatus and for making recommendations to farmers on attaining greater efficiency. In 1937 approximately 42,000,000 kilowatt-hours were consumed in Kings County, of which about 45 percent was used for agricultural power purposes. The average pump power cost for lifting 1 acre-foot of water 1 foot is 3.2 cents, according to figures supplied by the San Joaquin Light and Power Company. In addition to electrical power for pumping water, a few deep natural-gas wells in the lake-bottom areas are equipped to use the gas for power purposes. Deep strata containing natural gas are tapped when the wells are drilled, and in some places there is sufficient volume of gas emitted to be harnessed.

TRANSPORTATION AND MARKETS

In the early days (*22*) transportation was largely by way of toll roads and bridges, and by ferries, with Stockton the principal terminal. Today the main line of the Santa Fe Railway in the San Joaquin Valley serves Kings County, passing through Hanford and Corcoran. The Southern Pacific Railroad also serves the county by means of the Goshen Division branch running to Coalinga, an important oil-producing area in the southwestern part of Fresno County, and through Lemoore, Armona, and Hanford.

With trucking becoming increasingly important, the maintenance of a good highway system within the county and connecting with the main State highway network has become necessary. Paved highways now link various parts of the county and also connect with State and national systems. Three State highways pass through Kings County: Number 41 from Fresno passes near Lemoore, through Stratford, along the west edge of Tulare Lake bed, through Kettleman City and over the Kettleman Hills, and joins United States Highway No. 466 in San

Luis Obispo County; No. 33, which runs along the west side of the San Joaquin Valley, passes through Coalinga, Avenal, the Kettleman Plain, and then southward to cross United States Highway No. 466 in Kern County; and No. 198, which connects Coalinga, Lemoore, Armona, and Hanford to United States Highway No. 99, the main arterial highway for the San Joaquin Valley. A large number of paved county roads serve internal needs, and the connecting State highways lead to parts outside. A good paved road facilitates travel from Hanford to Fresno, the largest city in the San Joaquin Valley.

Grain is usually shipped to San Francisco or Los Angeles markets, where some is milled and some reshipped; barley is sometimes exported, mainly to England, for brewing purposes. Early fruits, chiefly apricots, peaches, and grapes, are generally sent fresh to eastern markets, but packing houses and canneries usually handle most of the crop for drying or canning, and in addition, San Francisco, Los Angeles, and local towns afford marketing places. A small market exists for long staple cotton in Los Angeles, where the fiber is used in making automobile tires. Milk is sold for local consumption and to local creameries, but the main market for dairy products is in the Los Angeles area. Beef cattle and lambs are marketed in San Francisco and Los Angeles, and wool is generally sent to San Francisco, where it is reshipped to the East.

Six marketing associations, organized to sell prunes and apricots, livestock, milk, grapes and raisins, walnuts, and cotton, take about 80 to 85 percent of the apricots and prunes, about 80 percent of the hogs, and most of the walnuts produced.

AGRICULTURE

The agriculture of Kings County, as well as that of much of the San Joaquin Valley, has evolved by means of three distinct stages. Cattle and sheep raising, wheat farming, and the present intensified and diversified farming that depends upon irrigation for the production of fruits, cotton, and alfalfa. Dairying is an additional important factor in the diversification of the agriculture. There have been no sharp divisions in time between the three stages, and even today cattle and sheep raising and wheat farming are important supplementary enterprises to dairying and to fruit, cotton, and alfalfa farming, but at one time cattle and sheep were of paramount importance as was also bonanza wheat farming.

Half-wild mongrel Mexican longhorn cattle made their appearance grazing on the plains of the valley early in the nineteenth century, at a time when there was only a small market for beef in California and little attention was paid to breeding for beef production. Hides and tallow were the main products—for which the mongrel longhorns were well suited. With the rapid rise of population, however, following the discovery of gold in 1849, and the consequent development of a good beef-cattle market, the Mexican longhorn gradually gave way to a better breed and the first stage of agriculture in the valley got well under way (*22*). Cattle raising was interspersed to some extent by sheep raising. The grass feed on the valley plains was dependent upon the low winter rainfall; fluctuations in the growth of grasses and in droughts, which killed scores of cattle and sheep, were not infrequent.

For some time ranchers enjoyed prosperous times raising cattle and sheep, but droughts and drops in market prices led some of them to experiment with wheat on the broad eastern slopes of the valley.

During the time that cattle were profitably raised some grain was grown in patches along the edges of streams, but later it was found that soils over broad stretches of the valley would also support excellent stands of wheat and barley, and soon vast areas of land were being cultivated. The advent of the railroad and the "no fence" law of 1871, a law that forced owners of cattle and sheep to build fences to keep their livestock from grazing over cultivated or farmed land, aided the development of the wheat farms that were soon to dominate the agriculture of the valley. Dry years and market price fluctuations had their effect on grain production, and it was soon evident that irrigation and a more diversified and intensified type of farming would have to be developed before stability of agriculture in the valley could be attained.

Fruit growing was begun in Kings County near Lemoore in 1885 The first fruit yielded well and was of good quality, and gradually, with the further development and extension of irrigation systems, there developed an irrigated fruit section in the general vicinity of Hanford, Lemoore, and Armona. Grapes, particularly the Muscat of Alexandria variety, were found to do very well and early became the leading fruit crop. Although grapes, peaches, and apricots early became important fruits, much of the present acreage used for these crops was planted from 1920 to 1930.

Dairying was initiated in the county in 1889, with the organization of a cooperative company for the manufacture of cheese. Previously most farms had a few dairy cows mainly for domestic needs, but with the establishment of a market, many farmers improved and increased their stock; alfalfa acreage increased; and gradually dairying grew until today it is one of the most important agricultural enterprises.

Experiments with cotton began when some Egyptian long staple was planted near Corcoran in 1906,[7] but though little came of this venture about 1920 some Durango, a short-staple variety, was tried. The Acala, a medium-long staple variety that is now grown exclusively in the San Joaquin Valley and Kings County, has an interesting history. In 1906 this superior type of upland cotton was discovered in the State of Chiapas in southern Mexico. Experiments conducted in California in 1915 by the United States Department of Agriculture proved that this variety was well suited to the natural environmental conditions of most of the cultivated part of the San Joaquin Valley. The advantage of planting one variety of cotton has long been realized, and the San Joaquin Valley afforded an isolated area where cotton production could be established and maintained on a pure-seed basis. With this in mind the United States Department of Agriculture set about providing for an assured supply of Acala seed to meet the demands of an increasing number of planters; the result was the establishment in 1923 of the United States Cotton Field Station at Shafter, from which each year a quantity of Acala seed is distributed to the farmers of the valley. The advantages of establishing one variety to the exclusion of all others and the superiority of this variety were so practically demonstrated

[7] See footnote 5, p. 12.

that a special act by the State legislature was passed in 1925 whereby no variety other than Acala cotton may be grown in the San Joaquin Valley. Acala was first planted in Kings County in 1923 and soon became one of the more important field crops.

As early as 1881 (*25*) settlers began to take up land along the edge of the Tulare Lake bed, and in 1884 some of the lake bottom was farmed to grain. At about this time the water of the lake stood at the lowest level then known, and farmers felt that the continually increasing use of water from the various rivers and streams that entered the lake for irrigation on higher land would keep the level at that low stage; consequently a large part of the lake bottom was cultivated for grain. The diversion of river water for irrigation purposes, however, was not enough in years of unusual snowfall in the Sierras to keep the lake level from fluctuating considerably, and sometimes disastrous results came to farmers on the lake bed. Nevertheless, because of the high yields of grain, farmers continued to take a chance with the lake, erecting small and large levees—a futile attempt at times—to hold back the water from their grain fields.

The extensive reclamation work that began about 1908 served to control the water to a large extent, confining it to a definite diked area, but record snowfalls in the Sierras in the winters of 1936–37 and 1937–38 were followed by spring and summer thaws that brought thousands of acre-feet of water down into the lowlands of the valley. Late in the spring and early in the summer of 1938 a number of reclamation districts went under the encroaching lake water; the huge levees, their height added to by last minute efforts of farmers, did not prevail against the reestablishment of Tulare Lake as a large body of water, and the flooding of section after section of excellent and uniform grain caused large losses to most of the farmers. Thus grain farming in Tulare Lake bed still remains an uncertain enterprise and probably will remain so until the floodwaters of the Kings River and of other rivers and streams entering the lake are more completely controlled, so that in wet years flooding will be prevented and in dry years sufficient water will be available for irrigation. Square mile after square mile of high-yielding grain that the soils of the lake bottom normally support remain as a vestige of the great wheat empire that once flourished in the San Joaquin Valley (pl. 1, *A*).

CROPS

Although the agriculture of Kings County is both intensive and extensive, the one-crop system is of paramount importance. Many crops are grown on the intensively farmed part north of Tulare Lake, but not until recently have rotations and cover crops been used to any considerable extent. Within the last few years the use of cover crops has increased. On the extensively farmed soils—the Tulare, Merced, and parts of the Chino and Hacienda soils—crop rotations are not practiced except by very few of the farmers. The crops produced are limited to grain, cotton, sugar beets, and corn, but cotton or wheat is usually planted in the same fields year after year despite the fact that alternate yearly plantings will increase or maintain the yield of both. The yield of cotton on the lake-bottom soils drops

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after 4 to 6 years of continuous planting. Any rotation with the four crops mentioned is good, but cotton and wheat will not successfully follow corn on the Tulare soils. The rotation most generally used on the intensively farmed part of the county is alfalfa 4 years, barley or corn 1 or 2 years, followed by alfalfa. Yields of grains are heavy, and fields are usually cleared of weeds that choked out the alfalfa. Cover crops in orchards consist of sweetclover (*Melilotus*), barley, or a planned volunteer crop. This latter is made up of the native annual plants, grasses, and weeds and is plowed under just after the seed has matured. In this manner it is self-seeding. *Melilotus* and barley must be plowed under while green, otherwise the soil nitrogen balance is disturbed and if the cover crop is grown in an orchard considerable damage may result to the trees.

The importance of the field crops to the county becomes evident by comparing the Federal census figures for 1939, when the three major field crops of wheat, barley, and cotton occupied 141,127 acres, whereas the fruits, nuts, and alfalfa acreage together occupied only 46,682 acres. Field crops of less importance are corn, sugar beets, and flax. These are handled in large tracts, frequently of several thousand acres each, and necessitate large money outlays for machinery, seed, labor, and other items. Data obtained from the United States census from 1900 to 1940 are shown in table 2.

TABLE 2.—*Acreage of principal crops and number of fruit and nut trees and grapevines*[1] *of bearing age in Kings County, Calif., in stated years*

Crop	1899	1909	1919	1929	1939
	Acres	*Acres*	*Acres*	*Acres*	*Acres*
Corn:					
For grain	2, 025	2, 274	4, 443	915	449
For other purposes			384	397	281
Oats threshed	110	109	237	46	1, 160
Wheat, total	32, 655	8, 684	51, 984	43, 392	7, 835
Winter				42, 401	6, 700
Spring				991	1, 135
Barley	2, 752	19, 287	21, 289	27, 243	101, 436
Sorghums for grain		3, 931	7, 751	5, 128	5, 882
Flax					2, 161
Cotton			640	25, 781	31, 856
All hay and sorghums for forage	[2] 59, 058	[2] 57, 276	41, 604	37, 528	41, 447
Alfalfa	24, 994	36, 778	30, 316	28, 446	28, 109
Small grain hay	6, 742	17, 629	10, 708	8, 235	12, 238
Other tame hay	115	2, 036	266	690	752
Wild hay	27, 207	833		46	14
Sorghums for silage hay or fodder			314	111	334
	Number	*Number*	*Number*	*Number*	*Number*
Peaches and nectarines, trees	253, 834	777, 697	402, 450	335, 131	222, 261
Plums and prunes, do	185, 489	132, 192	49, 829	70, 170	26, 233
Apricots, do	108, 161	124, 007	164, 112	287, 269	210, 801
Olives, do	332	5		14, 358	505
Nuts, do	1, 971	1, 747	1, 999	2, 484	7, 072
Grapes, vines	4, 218, 824	4, 538, 732	5, 608, 040	5, 758, 344	5, 039, 158

[1] Trees and vines as of census years 1900 to 1940, inclusive.
[2] Hay only.

The acreage in wheat changes from year to year, but Kings County normally leads the counties of the State in the production of this grain. Although the 69,599 acres in 1936 was the largest up to that time the average acreage is about 45,000 to 55,000 for the county.[8] In 1939, the average acre yield was 29.3 bushels, with yields of 35 to 42 bushels for the dark heavy soils of the Tulare Lake bed. The shallow

[8] Acreages compiled by J. C. Griswold, Sealer of Weights and Measures of Kings County.

roots of grain are affected but little by the salts occurring in the subsoil. Dry-farmed grain on the lake margin, largely occupied by the Hacienda soils, yields 8 to 12 bushels. The Merced soils in the vicinity of the Hacienda Ranch dry out too quickly for wheat to mature, as do the Panoche soils on the west side of the county. The wide yearly fluctuation in acreage is caused by the quantity of available irrigation water; only 40,000 to 50,000 acres of the better lake-bottom soils—the Tulare clay, clay loam, and loam—are irrigated from deep wells during the dry years. Little wheat is grown north of Dallas School and practically none west of the lake and the trough of the valley.

Between 80 and 90 percent of the wheat produced is of the Baart variety, 10 to 15 percent Sonora, and 1 to 5 percent Federation, with a very small percentage of Bunyip in some years. The Federation variety is more drought-resistant and for that reason is more generally grown on the west side of the lake. It also shatters less. The Sonora is grown on the east side, while the Baart occupies the south and west sides of the lake basin. Rust and smut are injurious during wet years, but resistant strains are being developed, and within a few years loss from this source is expected to be materially reduced. The most troublesome plant is alkali weed, and occasionally infestations of wild morning-glory are serious.

The large-scale production of wheat is made necessary by the expense involved for the protection of the field with levees from floodwaters in wet years and for deep wells to irrigate during the dry years. The very flat uniform relief of the lake bed favors the use of large machinery and permits the flooding of large areas with little preparation other than normal tillage operations. The hot, dry summers with only light winds leaves the grain in good condition to be harvested with the combine. About 1 to 2 acre-feet of water is necessary to produce a crop of grain, although the yields are greatly increased if additional water is available. The cost of water is from $3.50 an acre-foot for ditch water to $1.75 an acre-foot for the cheapest well water. Some of the ditch water coming into the southeastern part of the county is of very poor quality because of the high content of black alkali.[9] The usual culture procedure is to burn the straw and stubble of the previous crop, then to irrigate the fields late in summer and early in fall. This is followed by preparing the seedbed and planting in October and November. If the seasonal rainfall is less than 5 to 7 inches the fields are irrigated once again in February or March. Wheat occupies a definite place in the agriculture of the county, especially on the lake-bottom soils where irrigation water is normally limited.

The barley acreage fluctuates with the seasons. In 1939, according to the Federal census, 101,436 acres were planted, which was more than the combined acreage of all the other grains, cotton, flax, and forage crops grown for that year. It is largely confined to the Tulare soils of the lake bed, where an average yield of 40 to 50 bushels is normal, but a yield of 60 to 80 bushels is obtained if the land is heavily irrigated. Barley is also produced on the Grangeville, Foster, and Chino soils on the Kings River fan, but here the fields are small and little grain is harvested; most of the acreage is pastured or cut green for hay.

Cultural practices are the same as for wheat. Barley has the advantage, however, of being somewhat more drought resistant and of

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[9] See footnote 4, p. 8.

maturing 2 weeks earlier. Early maturing is very important during flood years, when large areas of the lake bed are likely to be submerged by an early summer rise in lake level brought about by drainage waters from the melting snows of the Sierras. Mariout variety is very drought resistant and for that reason is grown mostly on the west side of the lake bed, but the Atlas variety accounts for 90 percent of the total acreage. Barley will continue to be an important grain crop and, as in the past, its yearly acreage will fluctuate with the seasons and the quantity of irrigation water available.

Cotton acreage has increased from 640 in 1920 to 31,856 in 1939, and the yield has increased from 443 pounds in 1929 to 707 pounds in 1939. About 85 percent of the total acreage is grown in the lake bed (fig. 3, *D*) on the Tulare soils, where the acre yields are 1 to 1¾ bales. The salts in these soils cause an uneven growth of the crop so that a uniform field is rare. More water is required for cotton than for grain, and it must be applied during the summer months, when surface evaporation is high and conditions conducive to the rise of the salts of the subsoils to the surface. Cotton is produced on Chino clay in the vicinity of Dallas School with yields of about 600 pounds an acre. Here the soils are level and contain little alkali. A moderate acreage on the Grangeville and Foster soils yields an average of about 100 pounds an acre less than on the Tulare soils, but in a number of places yields of more than 2 bales are produced on soils that have not been farmed for some time. These yields, however, will probably not be maintained without the use of fertilizers or a rotation in which some legume is included. These soils are badly spotted with alkali, although the spots will produce a crop in most places if the plants can be brought through the seedling stage. Fields on these soils range from 20 to 60 acres in size, whereas the fields of the lake bed range from ½ to 3 sections. Some Chino fine sandy loam is farmed to cotton, although here the alkali condition usually interferes and the best yields are rarely more than 1 bale an acre.

The general cultural practice consists of burning the previous season's stalks, then plowing and irrigating. The cottonseed is planted from March 25 to May 1, but the earlier planting may rot because of inclement weather and then reseeding is necessary. When the young plants are 4 or 5 inches high, the fields are chopped and the plants thinned. Between June 20 and September 1, three or four applications of water are added. Water is applied both in furrows and in checks. About September 15 picking starts. The heavy Tulare and Chino soils require somewhat less than 3 acre-feet of water to grow a crop of cotton; the Grangeville, Foster, and Chino fine sandy loams about 3 or 4 acre-feet; and the Grangeville loamy fine sand more than 4 acre-feet. At Murray 4 to 5 acre-feet were applied to cotton planted on Panoche clay loam, and the yields for 1936 and 1937 averaged 678 pounds an acre. Though no rotation is now used on the Tulare soils, the yields of cotton begin to decline slightly after 4 or 5 years of continuous cropping. Sugar beets and cotton should make a good rotation.

Alkali weed on the Tulare soils and Johnson grass and Bermuda grass on the Grangeville, Foster, and Chino soils are the worst weeds encountered. The bean thrip does some damage to cotton planted on the Panoche soils and on the west side of the lake. Other trouble-

FIGURE 3.—Plantings of *A*, grapes; *B*, peaches, apricots, plums, and prunes; *C*, grain; *D*, cotton; *E*, alfalfa; *F*, approximate carrying capacity of pasture land in terms of cow-acres. One dot represents 20 acres, with a section as the unit of location. Data for crop maps obtained in the field and from the secretary of Kings County Agricultural Conservation Association, 1937. Location of major soil groups: Group 1 includes soils of the foothills; group 2, soils of the recent alluvial fans and flood plains; group 3*A*, well-drained soils of the old alluvial fans and valley plains; group 3*B*, poorly drained soils of the old alluvial fans and valley plains; group 4, soils of the valley basin; and group 5, rough mountainous land.

some insects are the cotton dauber, Say's stinkbug, and the cotton aphid. They are not prevalent every season, and some years are not troublesome at all. The diseases are most severe in damp weather during spring. Sore shank causes the young plants to rot off at the ground and is more severe in heavy-textured soils. Verticilium wilt may be injurious in certain fields, especially during cool weather in either spring or fall. Clean fields are the best control at present for these insects and diseases.

Labor to cultivate and pick the crop has been plentiful in recent years, but the large number of laborers required and the seasonal nature of the work have resulted in pressing social problems. Cultivation of cotton should continue to be an important factor in the agriculture of this section.

Flax has been grown on the Tulare soils in the lake bed, but late spring frosts damage the young plants. The fields are seeded in November, and the plants bloom in February when frosts are most likely to occur. Weeds also give some trouble on the Tulare soils. Flax produced at Murray is almost free of weeds and is damaged very little by spring frosts. The average yield on the Panoche soils is 20 bushels of seed an acre, whereas the yields in the lake bed are 2 to 20 bushels. Better harvesting machinery is now being developed. General market prices for the seed are good, and it is probable that the acreage will increase, especially on areas of the Panoche soils where water is available for irrigation.

The cultivation of sugar beets was revived in 1936 with the planting of curly top resistant varieties U. S. 33 and U. S. 34, the former being the commercial variety at present. Curly top, a blight, checked attempts to grow beets in 1919. Present attempts are still in the experimental stage, but test plots in 1936 produced yields of 18 to 20 tons an acre on the Tulare soils in the lake bed. Sugar beets are resistant to alkali and produce well in either heavy- or light-textured soils. The Tulare soils are very flat, however, so that irrigation waters do not drain away rapidly and thus cause scalding, especially if the plants are submerged for any length of time. Irrigation by means of a deep furrow between every other row would eliminate this danger. No sugar beets are grown on the Panoche soils in this county, but in Fresno County near the Kings County line the yield was about 8 tons an acre on Panoche clay loam in 1937.

Sugar beets require three irrigations in addition to the preirrigation. The seeds are planted from November to February, and the crop is harvested from June 15 to August, depending on the planting time. The unusual weather of 1938 checked the growth of the beets early in spring so that they stooled or went to seed with the second growth. The total acreage so affected was later submerged by the flooding of Tulare Lake. Such weather conditions, however, are not common and will not greatly affect the future development of the crop. Market conditions are not good in the valley, but they will undoubtedly improve as future acreages warrant. Sugar beets will work in well with cotton and grain farming on the Tulare soils, and they may produce good yields on Chino loam and clay loam. The successful production of such a crop will aid in solving the present labor problems because the harvest is during slack periods.

The yearly plantings of grain sorghums fluctuate a great deal. The most widely used varieties are Double Dwarf Milo, which is the

most popular, and Single Dwarf Milo. These are grown on the soils in the lake bed and on the Grangeville, Foster, and Chino soils of the Kings River fan, where the fields are usually small. The fields in the lake bed are large, and the grain is harvested with combines. The acreage is usually between 3,000 and 4,000, and the average yield is about 27 bushels an acre. This crop seems to be tolerant of moderate salt concentrations, but the yields are much better on soils containing little or no salts. Three irrigations are normally required. Yields of wheat and cotton on the Tulare soils are materially reduced when these crops follow the sorghums, but barley seems to be little affected. An application of 200 to 300 pounds of ammonium sulfate to the acre should correct this condition, which is probably caused by a disturbance of the soil nitrogen balance, as is the case when straw and stubble are plowed under on the Tulare soils. Grain sorghums are well adapted to this region, and the yearly plantings will depend on market prices and seasonal conditions.

Alfalfa is the principal hay and pasture crop, with an acreage of 28,109 in 1939. This is more than the combined acreage of all other hay and pasture crops. These hay and forage crops largely support the large dairy enterprise. The figures in table 2 show a steady decrease in acreage for alfalfa. These figures, however, include a large acreage that is watered only once or twice each season and from which only one or two cuttings are obtained. The steady decrease in this ill-tended acreage and the increase of well-cared-for fields account for the gradual increase in acre-tons harvested. The yield of alfalfa for the average farmer on the Grangeville and Foster soils is 1 ton for each cutting, or 6 tons an acre for the season; the yield on farms where the fields are kept level and the crop is watered regularly is 8 tons. In 1937 south of Corcoran about 1,995 acres seeded to alfalfa on Tulare clay loam had an average yield of 6 tons an acre for the season, whereas farms having better-than-average conditions produced 8 to 10 tons. On the Foster and Grangeville soils, where 75 percent of the alfalfa is grown, the fields are reseeded after 4 years, although the life of the crop on Tulare clay loam is about 6 years. The best quality hay is obtained during the second and third years and during the second, third, and fourth cuttings of the season. After 4 years, Johnson grass and Bermuda grass largely replace the alfalfa on the Grangeville and Foster soils.

The fields are commonly seeded from September to May after they have been leveled and irrigated. A fall planting will produce five cuttings the first year, whereas a spring planting yields only three. Chilean is the variety commonly grown. The land is generally irrigated between each cutting, but the lighter textured Grangeville soils often require three irrigations for each two cuttings. Best yields are obtained from fields where the checks are as level as possible so that the area is uniformly watered. Young seedlings are very sensitive to alkali, but if the roots can get below the surface accumulation of salts, the plant will withstand a moderate concentration. The young plant can be aided in getting started by keeping the field well watered or by the application of gypsum where the salt concentration is severe and accompanied by alkaline carbonates. Insects affecting alfalfa are limited to small infestations of alfalfa caterpillars and some cutworms. Light infestations of alfalfa wilt and alfalfa dwarf

also occur. Bermuda and Johnson grasses become a pest if allowed to go unchecked.

Practically the entire crop of alfalfa is consumed locally by dairy cattle; it constitutes their chief food. When sold the crop is baled, but when used on the farm where produced, as is usually the case, the hay is stacked in the open and fed from racks. During the latter part of the season some fields are used for grazing cattle and hogs.

The grains cut green for hay have remained about constant since 1900, with the yearly acreage ranging between 8,000 and 9,000. The yield is about 1.2 tons an acre. These grains, largely oats and barley, are produced almost entirely in small fields on the Grangeville, Foster, Chino, and Rossi soils in conjunction with the dairy enterprise. The grain is pastured in April and part of May and is cut for hay from June 1 to 15. The cured hay is stacked and fed as needed.

The area of permanent irrigated pasture has expanded rapidly in the last few years and now is between 500 and 600 acres. A mixture of grasses and legumes planted together are irrigated every 10 days or 2 weeks throughout the summer so that a green pasture is maintained for a period of 10 months of the year. A good pasture has a carrying capacity of 1 to 1½ cows an acre. The field should be divided into several plats and the cattle rotated. Pastures are not used when the fields are muddy during December and January. Irrigations should be rapid and light; it is not necessary to moisten the soil deeper than 18 inches. Best results are obtained on loam or clay loam soils, because the good moisture-holding capacity permits longer intervals between irrigations and the plants are less likely to be damaged than on light-textured soils. All plants of the original seeding mixture should be maintained in the pasture by reseeding any plant that dies out. The following mixtures are recommended by the county farm adviser:

For dairy cattle:	*Pounds an acre*
Ladino clover	4
Western ryegrass	4
Orchard grass or Dallis grass	5
Bur-clover	5
Alfalfa (optional)	5

For hog pastures:	*Pounds an acre*
Ladino clover	4
Alfalfa	5
Bur clover	5

The sorghums and Sudan grass each have an acreage of about 1,500. Sudan grass replaces the wheat, oats, or barley cut green for hay. The fields are small, and the grass supplies pasture until frost in fall. After freezing, Sudan can be no longer used for feed. Two or three irrigations are sufficient in summer. The sorghums are also planted in June and to some extent follow the grain cut for hay. Yields of 6 to 15 tons an acre are used almost entirely for silage, for which sorghum is well adapted.

The 1940 Federal census placed the area planted to orchard crops, including vineyards and fruit and nut trees at 18,573 acres, and the total value at $1,542,447.

Grapes are the most important of the orchard crops, with an acreage of 13,430.5 for 1936 (*4*). Apricots had the second largest fruit-bearing acreage in 1936, or 3,715.7, but peaches closely followed with an acreage of 3,278.6.

Table 3 brings out the general trend in plantings and yields over a number of years for the important orchard crops. The production of these crops, however, requires considerable time, and the

A, Wheat on soils of the Tulare series. Field on left has been prepared for the planting of cotton. Drainage ditch in foreground. *B*, Vineyard of Thompson Seedless grapes on Grangeville fine sandy loam.

A, Barley on Panoche loam. This was grown without irrigation in the season of 1938 of unusually heavy rainfall. In average seasons there is very little or no water available for irrigation on the Panoche soils. Kettleman Hills and town of Avenal in distance. *B*, Irrigated barley on soils of the Lost Hills and the Panoche series.

money outlay is much greater than for grains, cotton, or alfalfa. For these reasons table 3 brings out the recent planting trends, year by year, from 1930 to 1936.

TABLE 3.—*Acreage by years of fruit and nut plantings and the bearing and nonbearing acreage as of 1936 in Kings County, Calif.*[1]

Crop	Acreage standing in 1936 from plantings in—							Total 1936 acreage	
	1930	1931	1932	1933	1934	1935	1936	Bearing	Non-bearing
Apricots	86.0	89.3	54.4	44.4	19.0	73.8	132.5	3,715.7	269.7
Grapes:									
Raisin	31.0	27.5	25.0	29.0	65.0	132.5	68.7	12,392.6	266.2
Table	5.0	2.0		3.0		3.8		234.4	3.8
Wine	27.0	13.3	0	2.5	0	4.0	0	519.5	4.0
Peaches:									
Clingstone	21.7	12.0	0	2.0	8.2	0	68.0	349.4	78.2
Freestone	103.7	61.1	134.3	87.3	147.6	169.9	263.7	2,929.2	668.5
Plums and prunes	2.8	5.3	1.0	13.8	8.5	19.5	4.4	589.3	46.2
Almonds	1.7	0	0	0	0	8.7	17.0	6.5	25.7
Walnuts, English	11.3	7.0	3.1	4.0	33.0	12.1	0	125.2	105.5
Olives	0	0	0	0	10.0	5.0	0	266.3	15.0

[1] Statistical data taken from California Fruit and Nut Acreage Survey 1936 (29).

About 90 percent of the grape acreage is planted to the Muscat of Alexandria and Sultanina (Thompson Seedless) varieties, and of these two approximately 18 percent is Sultanina. The acreage of Muscat of Alexandria is the second largest in the State. The production of grapes is almost entirely limited to the Grangeville, Foster, and Dinuba soils (fig. 3, *A*). Muscat of Alexandria grapes, which are best adapted to the Foster soils and especially to Foster loam, will withstand considerable quantities of alkali after the roots have penetrated the soil deeply. The yields depend on the care given the vines and on local soil conditions, but the average is 4 or 5 tons an acre. Under better-than-average conditions and on good soil, farms will produce 6 or 7½ tons an acre. The Sultanina vines produce best on Grangeville fine sandy loam (pl. 1, *B*), and in many cases it is the only crop that can be successfully grown on Grangeville loamy fine sand. On the Foster soils these vines grow too rank and produce little fruit. Sultanina grapes will withstand a slight quantity of alkali. The average yield is 5 or 6 tons an acre on the better-cared-for farms.

Most of the Sultaninas (Thompson Seedless) and Sultanas (Round Seedless) are dried and sold as raisins, but the rest, together with the Muscat of Alexandria and all other varieties, are used largely for wine. Very few table grapes are shipped from the county. The grapes shipped to eastern markets are used largely for wine. Wineries within the valley absorb the rest of the crop.

The high water table on the Kings River fan makes surface irrigation of the wine grapes unnecessary except in special cases or during a long period of dry years. A good surface mulch is maintained by deep plowing, but the roots, because of their deep-rooting habits in these loose sandy soils, are apparently not damaged by deep cultivation. The only serious disease is powdery mildew, which affects both leaf and fruit. It is worse during cool years and is controlled by dusting with sulfur. The grape leafhopper may be serious, especially to the Sultanina and Malaga grapes during dry years. This pest is controlled by dusting with cyanide, pyrethrum sprays, or nicotine in an

oil spray. The vines have been damaged very little by a high water table. The acreage planted to grapes will fluctuate somewhat, depending on the general trend of prices, but the present plantings seem to represent a good average for the county.

Apricots on 3,985.4 acres in 1936 were 51.9 percent Tiltons, 42.8 percent Blenheims and Royals, and 5.3 percent Peach. The orchards are mostly within a territory extending 8 miles south of the Kings River and a little west of Lemoore (fig. 3, *B*). The Peachcots are sold as early fruit, but the quality is poor. The Tiltons are sold to the local canning companies or shipped to Los Angeles and San Francisco, and the Royals are sold as dried fruit. The average yield is between 3 and 4 tons of green fruit an acre. Cover crops are grown in a few orchards and some barnyard manure is used, but no commercial fertilizers are applied. The trees do better on the better drained areas of the Grangeville soils and are rarely found on the heavier textured Foster soils. A large percentage of the orchards are subirrigated by the high water table prevailing where most of the orchards occur. About half of the trees are on peach roots and the other half on apricot roots. A few trees are on myrobalon roots, but these roots are bothered with gum diseases and are slow-growing, although they seem to be the most resistant root on waterlogged soils. Peach roots seem to produce the best all-round trees. About 65 acres of the apricot trees were killed in 1937 because of a high water table and other complications.

The flat-headed apple tree borer causes some injury to young trees, and peach twig borers occur to some extent. Brown apricot scale, which is controlled by a dormant bordeaux or oil spray, is serious in some years. During recent wet seasons the Blenheims and Royals have been bothered by brown rot. Some years the crop is cut short by late spring frosts or unfavorable weather during the blooming period. The acreage has remained stationary for some time, but it will probably decrease during wet years. Poor markets in recent years have not encouraged setting out new orchards.

Less than 11 percent of the peaches grown are of the clingstone varieties. The Phillips Cling accounts for half of the acreage of the clingstones. In the order of their importance the other clingstone varieties are Paloro, Halford, Libbee, Peak, Tuskena, Hauss, and Johnson. The Phillips Cling ripens in fall, and the midsummer varieties are Peak and Paloro. Most of the clingstone peaches are canned locally. Elbertas make up 62.4 percent of the freestones, Lovells 19.8 percent, and Muirs 10.9 percent. J. H. Hale and Salway are two minor varieties. The Lovells and Muirs are dried, and the Elbertas are sold as fresh fruit, canned, and dried.

All the orchards are on peach roots. They are planted in larger orchards than are apricots, as is shown by figures gathered in 1936 (*4*) for the freestone varieties. Insect infestations are not severe but demand attention. San Jose scale and red spider are controlled by a lime-sulfur spray to which is added lead arsenate and oil. The peach twig borer and flat-headed apple tree borer give some trouble, and light infestations of nematode occur on the lighter textured soils. The most frequent diseases are curl-leaf, shot-hole fungus, little leaf, crown gall, and occasionally mildew on the fruit. Little leaf is controlled by a zinc spray, and a lime-sulfur or bordeaux spray controls most of the other diseases.

Peaches do best on the Grangeville soils where the water table is not too high. The orchards are subirrigated by the high water table, but during dry years they are watered from the surface. About 200 acres of trees died in 1937 from complications resulting from a high water table. A deep surface mulch is maintained to prevent excessive evaporation in summer. The trees are pruned low but not too open, because of the sunburning that would result. There has been a slight downward trend in acreage for the past few years, owing to market conditions and to the aging of many of the orchards.

The acreage in plums and prunes has shown a steady decline since 1900. Prunes are not well adapted to this climate, the fruit being small and of inferior quality. French and Imperials make up about 92 percent of the acreage. About 77 percent of the plum acreage is composed of the Tragedy and Santa Rosa varieties. The uncertain and erratic markets of the past have not encouraged large plantings, although plums seem to be adapted to the climate and bear well. Prunes are sold as dried fruit, whereas plums are shipped fresh to eastern markets. Plum trees do well on both the Grangeville and Foster soils, but they withstand waterlogged soil conditions much better than any of the other fruit trees now grown in the county. For this reason they grow well on the Foster soils, especially Foster loam. The trees are on myrobalan roots. A surface mulch is maintained in summer, and the orchards are usually subirrigated by the high water table. Red spider is the worst insect pest. There are no special or severe diseases. The prune acreage may continue to diminish, but the plum acreage may increase slightly within the next few years if market conditions seem to hold steady and if the high water table reduces the acreage of other fruit trees.

Commercial plantings of olives are limited to the Panoche soils in the vicinity of Murray. The 1936 acreage of 281.3 was chiefly Ascolano, 248; Sevillano, 18; Manzanillo, 10; and Mission, 0.3 acres. Olives have erratic bearing habits and yield high one season and low the next. The 230-acre orchard at Murray has an average yield of 350 to 400 tons per acre, but the 1937 yield was 163 tons. The fruit is of good quality, has large size, and is free from injurious insects and diseases. The orchards are mulched in summer and irrigated once a month from March to September. Early fall frosts may sometimes damage the fruit before it can be picked. Olive trees are hardy and long-lived. The present acreage will probably not increase much, especially in the vicinity of Murray, where water for irrigation is limited.

The nut crop is limited largely to English walnuts and almonds. although an occasional pecan tree is found in the yards of residences. The almond acreage decreased to 32 acres in 1936. The main varieties of walnuts are Franquette, Eureka, and Concord and of almonds are Texas, Nonpareil, Drake, Ne Plus Ultra, Peerless, I. X. L., and Eureka. The plantings are along irrigation canals and fence rows on the Grangeville soils. The trees are badly affected by red spider, and the yields are erratic. The acreage in English walnuts has been increasing within the last 10 years. The walnuts are grafted on the more hardy native black walnut roots and grow better on the Grangeville soils. Most of the trees are too young to be in full bearing, so that an average yield cannot be given, but 100 tons of nuts were pro-

duced in 1936. A good quality meat is obtained if the nuts are harvested before fall frosts, otherwise the quality is lowered by discoloration.

Miscellaneous plantings of other fruits, mainly for home use, include apples, pears, quinces, persimmons, figs, nectarines, and oranges.

Berries are produced for the local markets but not in sufficient quantity to satisfy the demand. They do best on Foster loam but grow well on Grangeville fine sandy loam. The plantings are all small and are usually a supplement to the grower's income rather than being produced on a commercial scale. Recently plantings of Boysenberries and Youngberries have been increasing. Both of these berries yield well and have excellent market qualities, such as flavor and firmness. The best fertilizer that can be used for berries is barnyard manure. If commercial fertilizers are used they should be high in nitrogen.

Vegetable production is limited almost wholly to home gardens. Tomatoes were formerly grown for canning, but the practice has been discontinued. Watermelons grow well on Grangeville fine sandy loam, but the commercial yearly acreage varies. Smaller fruits and vegetables are grown by some farmers.

FERTILIZERS

The use of commercial fertilizers in the county is limited to such an extent that it has little significance. All the important agricultural soils are young, and the semiarid climate does not supply enough moisture to leach the plant nutrients from the soil. Consequently the plant nutrients that are released by the weathering and disintegration of the rocks from which the agricultural soils are derived remain in the soil and are available to plants. Along with these nutrients certain salts accumulate that have a detrimental effect on plant growth. These salts are commonly known as alkali, and their nature and significance are more fully treated elsewhere in this report. An application of lime to any of the soils will have little or no beneficial effect as a plant food nutrient, nor will it produce a more desirable tilth or granular condition of the soil. No experiments on fertilizer test plots have been conducted to determine the plant nutrients, if any, that are needed to produce better yields. It is probable, however, that the most beneficial results would be obtained by the application of nitrogen in some form; whether the yields would be increased enough to defray the added expense is not known. Nitrogen-producing bacteria require a well-drained, well-aerated soil, and for this reason the heavy soils of the Tulare Lake are likely to have their nitrogen balance easily disturbed. Wheat and cotton cannot follow corn in the lake-bottom area unless the roots of the corn are plowed up and left on the surface or unless ammonium sulfate is added to the cornfield at the rate of 200 to 300 pounds an acre. The application of barnyard manure to the soils is a common practice and gives beneficial results. The use of superphosphate with other soluble phosphate fertilizers doubtless would produce substantial increases in yields of certain crops, especially alfalfa and sugar beets, on the more highly calcareous soils, such as the Panoche.

LIVESTOCK AND LIVESTOCK PRODUCTS

Dairying and livestock raising are closely associated with the production of grain and forage crops, although livestock does not consume all the grain produced. Operators grow a large part of their own feed, and most of the alfalfa is marketed locally as feed for the dairy herds.

Dairying is estimated to produce 15 to 20 percent of the agricultural income of the county.[10] The number of dairy cattle has steadily increased since 1900, and there are perhaps 30,000 head on 767 dairy ranches in the county. About 90 percent of the dairy cattle are of the Holstein-Friesian breed, 7 percent Jersey, and 3 percent Guernsey. Perhaps 500 head, or nearly 2 percent, are registered Holstein-Friesian stock. The average butterfat production is between 200 and 250 pounds, whereas the 2,000 head belonging to the cow-testing association have an average of 325 pounds. About 15 percent of the dairymen use purebred bulls. Considerable abortion is present, but only 1 to 2 percent of the cattle are tested for abortion. An internal parasitic disease, trichomoniasis, is also present, and mastitis causes much udder trouble. The average-size dairy herd is 35 to 45 cows.

The milk marketed locally is processed into butter, milk powder, ice cream, and dried milk by the two creameries in the county, the production in 1940 including 2,249,919 pounds of butter, 760,940 pounds of cheese, 94,905 gallons of ice cream, and 30,437 gallons of ice milk (*6*). Only 20 percent is marketed as sweet cream, and what is not consumed locally is sold in Los Angeles. Alfalfa as hay and pasture is the chief feed of the dairy cattle. Balanced rations are not used, although some concentrates, as crushed barley, are fed to a small extent. Grain and silage sorghums are grown and fed as silage or grain, or grazed in the field. Five percent of the dairymen have silos, many of the trench type, which seems to be satisfactory.

Dairying is well adapted to the region and has long been an established enterprise. The crop upon which it depends, namely alfalfa, produces well with moderate care and is generally tolerant of the alkali conditions found in the Kings River fan, where most of the dairies are operated.

Ranches for livestock, 95 in all, are largely centered west of the valley floor in foothill and mountainous parts. The poorly drained soils of the old alluvial fans and valley plains group—the Pond, Fresno, Lewis, Traver, and Chino—are also largely used for spring grazing, and when the grasses dry up the cattle are moved to other pastures. Although an average of 10,000 cattle are finished for the market each year, they are largely imported as feeders. About 2,000 breeding cattle remain in the county. The actual number of beef cattle depends on the quantity of feed available and the season of the year. Cottonseed cake is used to fatten 5,000 to 7,000 steers at Corcoran yearly. All cattle are vaccinated for blackleg and tested for tuberculosis.

The number of sheep and lambs depends upon the acreage available for grazing. The census reports 17,646 for 1940. They graze mostly on the Kettleman Hills, the Kettleman Plain, and on the Lethent

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[10] Much of the data on livestock activities was obtained from George H. Bath, Assistant Farm Adviser of Kings County.

soils lying north of the Kettleman Hills. The grass on these areas is largely gone by May 1, and then a few of the flocks move back into the mountains, where the grass stays green for perhaps a month longer. Other flocks are moved to new pastures in the Sierras or to other places in the valley. In summer much of the grain stubble is used for grazing, the sheepmen renting it from the grain farmers. Lambs are dropped in November and December, and many early spring lambs are sold in Los Angeles and San Francisco. Rambouillet is the most common of the many breeds raised. The sheared fleeces commonly weigh 5 to 7 pounds. Locoweed has been spreading within the last few years, and a considerable number of sheep eating it are killed, but the danger from this poisonous plant is less when other green growth is available.

The carrying capacity of any of the grazing lands depends entirely upon growing conditions in spring and seasonal rainfall. Unless very lightly grazed, few of the pastures will carry a herd or flock through the entire year. The fields are commonly grazed from November to June, and then the livestock is moved to other pastures outside the county or to a stubble field. The value of forage is largely measured by the quantity of alfileria and bur-clover present, although foxtail is also important and is the best feed in November and December. Saltgrass is poor feed, and consequently such soils as the Fresno, Pond, and Hacienda have low grazing value. *Atriplex* has some browsing value for sheep. The grass of the Kettleman Hills, though thin and short, has good feeding quality. The Middle Dome and especially the North Dome have little grazing value. The rough mountainous land is used largely for cattle, although late in spring some few flocks of sheep move in from the Kreyenhagen Hills. In pockets and on small level areas grass is good, but brush and scrub timber increase in the higher altitudes and grazing is poor. Water is found only at the bottom of canyons, and in summer livestock cannot graze too far from the water holes. The cross section of the county shown in figure 2 illustrates the general distribution of the native vegetation and the areas chiefly grazed by cattle and sheep. Figure 3, *F* shows the average range in the number of acres required to graze a steer, but seasonal fluctuations are sometimes great and none of this range will carry a herd the year round.

The common swine breeds are Hampshire and Duroc-Jersey with a few Poland China. They are produced almost entirely within the intensive agricultural area, the northeastern third of the county. The Federal census reports 6,848 head in 1940, a marked decrease from the 40,633 reported for 1910. There are few purebred herds, though in general a good grade of hog is produced. They are fed ground barley and some milo and are allowed to graze on alfalfa pasture. No small grains are "hogged down" in the field, and skim milk is not used as a feed. Perhaps 10 percent are vaccinated for cholera, but the outbreaks are rare. More hogs could be produced, although there is no special advantage for their production not found in other counties of the valley. Nearly 80 percent are sold through the Kings County Farm Bureau Marketing Association and eventually to San Francisco or Los Angeles markets.

The number of horses has steadily declined since 1910, when the Federal census reported a peak of 11,473, compared with 4,219 reported for 1940. The census reported 958 mules in 1940.

A slight increase in chickens is evident, but practically the entire number, 122,909, reported by the census in 1940 can be classed as farm flocks for added income to ordinary farming operations. Turkeys and ducks have no commercial significance.

In 1940 the census reported 2,558 colonies of bees and estimated their value at $8,569. The colonies are moved by motortruck to different parts of the valley where seasonal flowers are abundant.

FARM TENURE

Of the 2,132 farms in Kings County in 1940, full owners and part owners operated 1,633, managers 36, and tenants 462. Systems of rental are of two kinds, cash and share. Tenants on land for cotton in the lake bottom, when renting on a share-crop basis, pay rent in one-fifth to one-fourth of the crop picked and delivered at the gin. A sliding scale is used for cash rent, the minimum charge being $10 an acre and an additional dollar for every cent rise in the market price of cotton above a certain set price, which for the last few years has been 10 cents a pound. Share rentals of one-fifth to one-fourth of the crop are used almost exclusively in the intensively farmed part of the county around Hanford and Lemoore. Occasionally rentals of the dairy farms are on a sliding scale, with the price of butterfat as the determining base.

FARM INVESTMENTS AND EXPENDITURES

The Federal census for 1940 reported 507,165 acres as the total land in farms, 312,195 acres of which were available for cropland; and of this, 61,776 acres were plowable pasture land, 178,463 cropland harvested, and 12,441 irrigated pasture. There were 2,132 farms with an average acreage of 237.9. The total value of the farm land and buildings is $31,781,929, the average value per farm $62.67 an acre, and the average farm value $14,907.

Nearly all the farms are near good roads. According to the 1940 census, 832 were on hard-surfaced roads, 1,149 on improved dirt roads, 133 on unimproved dirt roads, and 2 on gravel or shale roads.

The farms are well mechanized. The soils in the Tulare Lake bottom are farmed with large tractors of the caterpillar type, while smaller wheel tractors have largely replaced horses and mules on the small- to moderate-sized farm. Water is pumped largely by electric power, although some gas and gasoline engines are used. There are a few milking machines. In 1940 there were 3,146 automobiles on 1,939 farms, 561 motortrucks on 455, and 985 tractors on 712.

Seasonal farm labor demands have always been met by drawing from the ranks of transient labor, which has been plentiful in recent years. Both Mexican and Negro workers are available but recently their numbers have been exceeded by migratory white workers from drought-stricken areas. The quality of this labor is average, considering the large numbers present, and the quality of Mexican labor seems to be improving. The better class of migratory white workers will buy or rent small ranches and thus become citizens of the community, but the influx at the present time is so great that serious social problems arise. Most of this labor is housed in labor camps, and a large proportion requires county aid during seasons of slack work. The labor required in the more intensively farmed area is of a more per-

manent nature and is mainly represented by a better class of Mexican and white workers. In 1939, 75 percent of the farms, or 1,599, spent $2,133,255 for labor, an average of $1,334.12 each.

SOIL SURVEY METHODS AND DEFINITIONS

Soil surveying consists of the examination, classification, and mapping of soils in the field and the recording of their characteristics, particularly in regard to the growth of various crops, grasses, and trees.

The soils and underlying formations are examined systematically in many locations. Test pits are dug, borings are made, and exposures, as in road or railroad cuts, are studied. Each excavation exposes a series of distinct soil layers, or horizons, called collectively the soil profile. Each horizon, as well as the underlying parent material, is studied in detail, and the color, structure, porosity, consistence, texture, and content of organic matter, roots, gravel, and stone are noted. The chemical reaction of the soil and its content of lime and salts are determined by simple tests.[11] The drainage, both internal and external, and other external features, as the relief or lay of the land, are taken into consideration, and the interrelation of the soil and vegetation is studied.

The soils are classified according to their characteristics, both internal and external, with special emphasis upon the features that influence the adaptation of the land for the growing of crop plants, grasses, and trees. On the basis of these characteristics the soils are grouped into classification units, the three principal of which are (1) series, (2) type, and (3) phase. In some places two or more of these principal units may be in such intimate or mixed pattern that they cannot be clearly shown separately on a small-scale map but must be mapped as (4) a complex. Some areas as riverwash and rough mountainous land that have no true soil are called (5) miscellaneous land types.

The series is a group of soils having the same genetic horizons, similar in their important characteristics and arrangement in the soil profile, and having similar parent material. Thus, the series comprises soils having essentially the same color, structure, natural drainage conditions, and other important internal characteristics, and the same range in relief. The texture of the upper part of the soil, including that commonly plowed, may vary within a series. The series are given geographic names taken from localities near which they were first identified. Foster, Panoche, Chino, Traver, Merced, and Tulare are names of important soil series in Kings County.

Within a soil series are one or more types, defined according to the texture of the upper part of the soil. Thus, the class name of this texture, as sand, loamy sand, sandy loam, loam, silt loam, clay loam, silty clay loam, or clay, is added to the series name to give the complete name of the soil type. For example, Tulare loam, Tulare clay loam, Tulare fine sandy loam, and Tulare clay are soil types within the Tulare series. Except for the texture of the surface soil, these types

[11] The reaction of the soil is its degree of acidity or alkalinity expressed mathematically as the pH value. A pH value of 7 indicates precise neutrality; higher values, alkalinity; and lower values, acidity. Indicator solutions are used to determine the reaction of the soil. The presence of lime in the soil is detected by the use of a dilute solution of hydrochloric acid.

have approximately the same internal and external characteristics. The soil type is the principal unit of mapping, and because of its specific character it is usually the unit to which agronomic data are definitely related. In comparisons of the type and phases of that type, to avoid the repetition of their complete names, the type is sometimes referred to as the normal phase.

A soil phase is a variation within the type, differing from it in some minor feature, generally external, that may be of special practical significance. For example, within the normal range of relief for a soil type some areas may be adapted to the use of machinery and the growth of cultivated crops and others may not. Differences in relief, stoniness, and degree of accelerated erosion may be shown as phases. Even though no important differences may be apparent in the soil itself or in its capability for the growth of native vegetation throughout the range in relief, there may be important differences in respect to the growth of cultivated crops. In such instance the more sloping parts of the soil type may be segregated on the map as a sloping or a hilly phase. Similarly, some soils having differences in stoniness may be mapped as phases even though these differences are not reflected in the character of the soil or in the growth of native plants. An example in the Tulare series is Tulare fine sand, beach phase.

The soil surveyor makes a map of the county or area, showing the location of each of the soil types, phases, complexes, and miscellaneous land types in relation to roads, houses, streams, lakes, section and township lines, and other local cultural and natural features of the landscape.

SOILS

The soils of Kings County fall naturally into four groups, on the basis of relief and from the standpoint of soil characteristics and land use. These groups are (1) soils of the recent alluvial fans and flood plains, (2) soils of the old alluvial fans and valley plains, (3) soils of the valley basins, and (4) soils of the foothills. Superficially the county is divided into three parts of about equal size: That part west of the valley floor which is used largely for grazing; the Kings River fan in the northeastern third, where intensive agriculture occurs; and the Tulare Lake Basin, where extensive agriculture is practiced. This division, though most apparent to the casual observer, is incomplete both from the soil grouping and the agricultural point of view.

The parent material of the soils is derived from both igneous and sedimentary rock sources. The sedimentary rocks are largely limited to sandstones and calcareous shales, and the soils derived from them occur only west of the valley floor; whereas the parent material of soils lying on and east of the valley floor is derived mainly from alluvium having its source in granitic rocks. The soils derived from material of granitic origin usually contain a large proportion of quartz and variable quantities of phosphorus, potash, and lime and generally have a light color. Calcareous sedimentary rocks are variable in character but generally have a good supply of potash, phosphorus, and lime. Organic matter and nitrogen are the most deficient in the soils of the area, and the supply of available phosphorus may be a limiting factor for the growth of some crops on the more calcareous soils.

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Several factors in addition to parent material enter into the formation and development of a soil. Climate, relief, drainage, the quantity and kind of vegetation under natural conditions, and the occurrence of salts all tend to produce the soil and to influence its color, texture, chemical composition, and fertility.

SOIL SERIES AND THEIR RELATIONS

The location and relative extent of the four soil groups, together with the two subdivisions based on drainage in group 3, are shown on the small sketches in figure 3. The location of the plantings of the more significant crops clearly indicate the relative importance of each of these groups. The relation between the relief, the soils, the native vegetative cover, and use made of these soils is shown in figure 2. It represents a cross section of the county, extending in a straight line from a point 4 miles east of the southwest corner to the northeast corner. It crosses soils belonging to each of the soil groups. Rough mountainous land and riverwash are classified as miscellaneous land types and are not included with the major soil groups.

Progress in the study of soil morphology and soil classification has brought about changes in the concept and definition of some of the soil series recognized in the earlier and less detailed surveys and has resulted in more accurate correlation and classification. Greater detail in mapping on larger scale, with more intensive field studies and benefit of an intervening period in which most of the present-day science of soil classification has been developed, has given rise to apparent wide conflicts in classification in this and the earlier surveys. The more conspicuous and important of these are noted in the descriptions of the soils.

In the following pages of this report the soils of Kings County are described in detail and their agricultural relationships and values discussed. The location and distribution of each soil type [12] and soil phase is shown on the accompanying soil map, and their acreage and proportionate extent are given in table 4.

SOILS OF THE RECENT ALLUVIAL FANS AND FLOOD PLAINS

The soils of the recent alluvial fans and flood plains represent the best soils for intensive agricultural practices in Kings County. Characteristically they are medium- or light-textured and more than 6 feet deep (with the exception of the Dinuba soil), are brownish gray, brown, or dark gray, are of recent accumulation, and have very little or no subsoil compaction or clay accumulation. The open subsoil favors root penetration and good internal drainage. Relief ranges from sloping to very gently sloping alluvial fans upon which surface drainage ranges from good to slow. The recent soils of the gently sloping Kings River delta or alluvial fan, represented by the Grangeville, Foster, and Dinuba series, consist mainly of soil materials originating in the granitic Sierra Nevada; whereas the soils of the Panoche series occupy the smaller and somewhat steeper confluent fans that form alluvial aprons around the sandstone and shale hills of the western part of the area. In addition to the division of the group on the basis of mineralogical character, a second division on the basis of drainage

[12] When a soil type is subdivided into phases, that part of the type that bears no phase name will be referred to as the normal phase of the type.

TABLE 4.—*Acreage and proportionate extent of the soils mapped in Kings County, Calif.*

Soil type	Acres	Percent	Soil type	Acres	Percent
Chino clay	4,800	0.5	Lost Hills loamy fine sand	2,432	0.3
Chino clay loam	10,048	1.1	Merced adobe clay	4,544	.5
Chino fine sandy loam	12,544	1.4	Merced clay loam	9,984	1.1
Chino loam	21,312	2.4	Merced loam	2,560	.3
Commatti clay loam	512	.1	Merced silty clay loam, shallow phase (over Lethent soil material)	4,096	.5
Shallow phase	1,536	.2	Nacimiento clay	1,088	.1
Dinuba sandy loam	1,088	.1	Panoche clay loam	17,792	2.0
Foster clay	960	.1	Panoche fine sandy loam	29,440	3.3
Foster clay loam	4,160	.5	Beach phase	832	.1
Foster fine sandy loam	22,976	2.6	Panoche loam	10,368	1.2
Foster loam	16,768	1.9	Panoche loamy fine sand	4,864	.6
Foster sandy loam	5,248	.6	Pond loam	1,088	.1
Fresno fine sandy loam	5,376	.6	Riverwash	896	.1
Fresno loam	1,152	.1	Rossi loam	11,520	1.3
Grangeville fine sandy loam	75,264	8.5	Rough mountainous land	40,384	4.6
Hummocky phase	2,240	.3	Temple loam	2,496	.3
Grangeville loamy fine sand	25,216	2.8	Traver fine sandy loam	13,248	1.5
Grangeville sandy loam	2,752	.3	Traver loam	640	.1
Hacienda fine sandy loam	11,648	1.3	Tulare clay	151,104	17.1
Deep phase	15,680	1.8	Tulare clay loam	37,760	4.3
Hacienda loamy sand	7,744	.9	Tulare fine sand	8,896	1.0
Deep phase	3,968	.4	Beach phase	4,160	.5
Kettleman-Altamont complex	17,728	2.0	Tulare fine sandy loam	38,464	4.3
Kettleman loam	88,960	10.1	Tulare loam	24,320	2.8
Lethent silty clay loam	61,760	7.0			
Hummocky phase	10,496	1.2			
Lewis clay loam	3,392	.4	Total	883,200	100.0
Lost Hills clay loam	3,904	.4			
Lost Hills fine sandy loam	20,992	2.4			

is possible. The dark-colored Foster soils are poorly drained and are normally affected by a high ground-water table. The Grangeville soils lie in an intermediate position between the poorly drained and well-drained soils, and they also are affected somewhat by a high water table but not so seriously as are the Foster soils. The brownish-gray Panoche soils and brown Dinuba soils are well drained and free from the effects of a high water table.

These soils are well adapted to deep-rooted crops, as fruits, where the water table is not too close to the surface. Grapes, particularly those used for wine, do very well on the Kings River delta and in general are more tolerant of high water-table conditions than orchard fruits, as peaches and apricots. Good yields of alfalfa and cotton are obtained. On the more poorly drained soils, where forage crops are grown more successfully, dairying is an important enterprise. In places the soils are affected by variable quantities of alkali, and where such conditions prevail, the degree of salt concentration is usually the limiting factor in productivity. The intensive agriculture of this area is dependent on the water supply for irrigation. Some potentially productive soils, as the Panoche soils in the western unwatered part, support only a native cover of bromegrass, foxtail, alfileria, and other annuals that afford some grazing for sheep and beef cattle in spring and early in summer. In a few places where good well water is available, good yields of cotton, olives, and grain are obtained from the Panoche soils. This group includes the Grangeville, Foster, Dinuba, and Panoche soil series.

GRANGEVILLE SERIES

The Grangeville soils are deep and permeable soils developed from recent alluvium originating principally from granitic rock sources. They occupy much of the gently sloping Kings River fan, which has

a somewhat irregular surface configuration formed by swales and numerous shallow sloughs or old stream channels with low stream-built ridges. Before the levees that now control the Kings River in flood stage were constructed, water flowing over much of the fan deposited variable increments of alluvial soil material. The soils are open, permeable, and free from compact layers. Drainage is fair, with the ground-water level fluctuating between 5 and 15 feet, but in very wet years it may rise to within 1 or 2 feet of the surface in some areas.

The 6- to 24-inch surface soil is generally light-textured, low in organic matter, moderately or only slightly calcareous, micaceous, loose, and open, and is grayish brown or light grayish brown when dry and darker grayish brown when moist or wet. It is easily worked and produces a friable soft lumpy tilth that forms a good seedbed. The subsoil is generally a little lighter in color than the surface soil, but in most respects the two are similar, being calcareous, micaceous, loose, and open. They differ principally in that the subsoil has some rust-brown streaks or mottlings of oxidized iron, which indicate incomplete drainage. The subsoil normally extends to a depth of 30 to 45 inches. Deeper material consists of light grayish-brown or light brownish-gray moderately or slightly calcareous, micaceous, stratified material of variable but generally light texture. Layers of loamy and of coarse sand commonly occur, and usually some rust-brown mottling is present; otherwise the lower material does not differ markedly from the subsoils.

Areas of these soils that have low productivity generally indicate an alkali problem. Much of this series is affected by a spotted alkali condition; some areas are moderately affected, and others strongly affected, by salt concentrations. Reclamation is possible because of the permeable nature of the soils, but it is not practicable until the ground-water level is lowered sufficiently to prevent the return of salts through evaporating capillary water rising from the high water table. These soils are related to and associated with the Foster series, which is more poorly drained and of darker color.

The Grangeville is a newly established series of soils not recognized in the previous surveys. In the earlier soil survey of the Pixley area these soils join with the related soils of the Cajon series, with which they were at that time included. Like the Cajon, they are brown calcareous soils with similar subsoils but occupying a flatter relief, are not so well drained, and usually have a relatively high water table.

FOSTER SERIES

Members of the Foster series are also deep permeable soils developed from recent alluvium originating principally from granitic rock, but differing from the soils of the Grangeville series in that they are imperfectly or poorly drained. In general they occupy the nearly flat or very gently sloping more depressed or lower parts of the Kings River delta, where old slough channels and their low stream-built flood banks give the surface some unevenness. Before the Kings River was brought fully under control, much of the area where the Foster soils occur was of marshlike character, which favored the growth of tules and other water-loving plants and the accumulation of more organic matter than is normal under this climate in well-drained soils. Recurrent deposition of alluvial materials by floodwaters of the Kings River has also

tended to maintain the soil profiles in a very young stage of development. Ground-water level fluctuates between 2 and 10 feet, being highest late in spring and early in summer, when the streams and canals are full.

The dark-gray to dark brownish-gray surface soil is 8 to 20 inches thick. Generally it is calcareous, although in places it may be only slightly so or even noncalcareous, but regardless of free lime content it has a moderately alkaline reaction. The lighter textured soils are easily worked into a friable or firm lumpy condition and usually break rather readily to a loose fine-grained mass; whereas the heavier textured soils break into firm or hard coarse clods that may be worked down into finer clods with some difficulty. The surface soil is micaceous and normally contains a moderate quantity of organic matter. The 25- to 40-inch subsoil is structureless and generally of the same texture as the surface soil, is usually calcareous, micaceous, and of a dark brownish-gray or gray color that is somewhat variegated and stained by brown streaks and spots of oxidized iron. Underlying material consists for the most part of gray, brownish-gray, or grayish-brown calcareous or noncalcareous micaceous stratified material of variable texture, highly mottled with rust-brown stains. Generally the texture does not vary a great deal from that of the surface soil, but layers of loose coarse sand commonly occur, particularly in the lighter textured soil types. There is little or no development in the soil profile. Internal drainage takes place freely where the water table is not too close to the surface, although it may be somewhat slow in the heavier textured members of the series. Spotted alkali conditions generally prevail in these soils, but some areas are moderately affected and others may be strongly affected by salts.

The Foster soils are related to and associated with the Chino soils, which represent a somewhat older stage of development, and with the browner better drained Grangeville soils. Where associated with the Grangeville soils, the Foster soils generally occur in small enclosed basins, low swales, or other depressions, with the Grangeville soils on the higher and surrounding land, often separated by differences of only 2 or 3 feet in elevation.

DINUBA SERIES

Dinuba sandy loam is the only type of its series mapped. This soil consists of permeable alluvial material of granitic origin that overlies a consolidated substratum and occupies the gently sloping upper part of the Kings River delta, where shallow old stream channels and low ridges give the surface some irregularity. Surface drainage is good, but internal drainage may be restricted by the impermeable substratum.

The 10- to 12-inch surface soil is grayish brown, becoming nearly dark brown when wet or moist; it is noncalcareous, micaceous, structureless, and generally of coarse texture, and is easily tilled, breaking readily into soft lumps or a loose fine-grained mass. The light-textured subsoil is very similar in most characteristics to the surface soil, and there is a gradual gradation from one to the other; however, it is generally a little lighter in color and is calcareous with occasionally a very slight quantity of segregated lime at lower depths. The subsoil is 36 to 60 inches thick, where it rests very abruptly on a gray calcareous hard-

panlike substratum 11 to 25 inches thick. Seams of hard highly calcareous material extend through the hardpan, and occasionally large tubular voids coated by thin layers of hard material also occur. Often sandwiched between this hard substratum and another similar layer at a lower depth is a layer of loose sandy loam or loamy sand that is similar in many respects to the subsoil. Root growth is definitely restricted to the relatively recent overwash soil material above the hard substratum, and moisture movement is arrested or restricted by the hard layer. The soil is largely free of harmful concentrations of salts, but some areas have a spotted alkali condition and others are affected by moderate salt concentrations. The surface soil and subsoil are similiar to those of the Grangeville series, with which the Dinuba series is generally associated, although the Grangeville soils do not have a hard substratum. The substratum is harder and thicker than is typical of Dinuba soils occurring in other areas.

PANOCHE SERIES

Members of the Panoche series are deep permeable soils developed from recent alluvium originating from calcareous sandstone and shale rock.

They occupy the smooth sloping alluvial fans lying at the base of the hills in the southwestern part of the area (pl. 2, *A*). Surface drainage is good, and steep-sided deep gullies, or barrancas, formed by small drainage channels are not uncommon.

The light brownish-gray to light grayish-brown surface soil is 9 to 18 inches thick. It is calcareous and structureless for the most part, and where cultivated breaks down fairly easily to a coarse granular structure in the heavier textured soils and to a loose fine-grained mass in those of lighter texture. The subsoil, which extends to a depth of 35 to 45 inches, is similar in color and other respects to the surface soil, although generally it is slightly firmer and may contain small quantities of segregated lime. The subsoil texture is somewhat variable but does not differ greatly from that of the surface soil. The deeper underlying material is light grayish-brown or light brownish-gray calcareous stratified material of variable texture. In places in the lighter textured soil types, layers containing some sandstone and shale gravel may occur. Much of the Panoche soil area is inherently affected by slight concentrations of alkali, mainly sulfates, although some areas are entirely free of injurious salt accumulations. The soils are related to and associated with the Lost Hills soils, which represent an older stage of development.

SOILS OF THE OLD ALLUVIAL FANS AND VALLEY PLAINS

Soils of the old alluvial fans and valley plains, for the most part, have a high alkali content, and all have well-defined surface soil and subsoil layers. Most of the area is used for grazing purposes for which the soils show a wide range of adaptation. The soils are considered under two subgroups, the well-drained and the imperfectly and poorly drained soils.

The well-drained soils comprise the Lost Hills and the Commatti series. A brown or light-brown surface soil containing a small content of organic matter characterizes the surface soils of this group.

The subsoils are firm or compact though not dense enough to greatly impede subsoil drainage or root penetration. They are developed from transported alluvium derived from sedimentary rocks and from material eroded from soils developed on sedimentary rock. The relief is sloping and of an alluvial-fan character so that the surface drainage is good or excellent. These soils are used entirely for grazing and support a grass cover of good grazing value.

The imperfectly and poorly drained soils of this group include the soils of the Chino, Traver, Lewis, Pond, Fresno, and Lethent series. The last-named is developed from alluvial material derived mainly from sandstones and shales, whereas the others are developed from alluvial material having its source mainly in igneous rocks largely of a granitic character. A high alkali content with a dense claypan or hardpan subsoil is characteristic of most of these soils. The surface is nearly flat, and internal drainage is usually limited by the high water table and the dense heavy-textured subsoils. A further division of this group on the color of surface soil is possible. The Traver, Lewis, Pond, and Fresno series have light-gray surface soils with a very low content of organic matter, whereas the Chino and Lethent soils contain moderate to large quantities of organic matter and are darker in color. The Lethent soils, however, have a brown surface soil. These soils are generally used for grazing, as the alkali content is usually too high to allow successful cultivation. The Chino soils, however, are cultivated to a small extent, but yields are considerably lower than those from the better soils of the county.

LOST HILLS SERIES

The soils of the Lost Hills series are developed from old alluvial material that originated from sandstone and shale rock sources. The lightered textured soil types generally occupy the higher and somewhat older smoothly sloping alluvial fans that lie along the eastern bases of the Kreyenhagen and Kettleman hills (pl. 2, *B*). The heavier textured soils, and in some places the fine sandy loams, generally lie at the outer edges of alluvial fans or on the floor of small valleys, as on the Kettleman Plain, where deposition occurs so infrequently and in such small increments that a distinct heavy subsoil layer has developed. Surface drainage is good, particularly on the lighter textured soils, in which some deep gullies, or barrancas, have been cut by small intermittent streams.

The 6- to 20-inch grayish-brown to light grayish-brown surface soil is slightly calcareous. The lighter textured soils are for the most part loose and fine-grained, whereas the heavier soils crack when dry and develop firm to hard clods that are broken down with difficulty to a granular or small lumpy mass. The surface soil generally rests rather abruptly on the slightly permeable subsoil, which is normally heavier textured than the surface soil and moderately compact. The dark-brown or brown subsoil has a fairly well developed firm or hard medium-blocky structure, the units of which are somewhat stained by dark colloidal material. Lime accumulations occur as thin white coatings on small tubular pores or along cracks and on surfaces of the structural units. Underlying parent material normally occurs at a depth of 30 to 50 inches, and consists of relatively permeable calcareous brown or light brownish-gray somewhat stratified ma-

terial, which, however, does not usually vary greatly in texture from the surface soil.

Most areas of these soils are slightly affected by alkali inherited from the parent rock. The Lost Hills soils are related to the Panoche soils, which represent a more recent or younger stage of development.

COMMATTI SERIES

Soils of the Commatti series are derived from alluvial material that originated mainly from sandstone and shale rock. In this area they occupy some of the narrow sloping bottom lands of small valleys in the hilly southwestern part of the county.

The dark-brown to dark grayish-brown surface soil is 12 to 20 inches thick, slightly calcareous or noncalcareous, and generally heavy textured and breaks into firm or hard coarse clods when dry. The surface soil is not high in content of organic matter, but has numerous grass roots, worm holes, and small root holes or tubular pores. The brown subsoil is normally somewhat heavier in texture than the surface soil and is slightly compact. A few vertical cracks occur when the subsoil is dry, and normally considerable white lime accumulations are present in and along the small branching tubular pores, giving the appearance of a myceliallike growth. At a depth of 30 to 45 inches, the subsoil is underlain by brown or light-brown heavy-textured calcareous friable material. The slight to moderate subsoil development and the outstanding thin lines of white segregated lime against the dark-colored subsoil layers are prominent features of this soil.

This series is represented by soils that occur on old alluvial material that originated from mixed but chiefly metamorphosed sedimentary rock sources.

CHINO SERIES

The Chino series consists of a dark-gray calcareous poorly drained surface soil with a moderately compact subsoil derived from parent alluvial materials of mixed granitic alluvium that lie on the outer and lower edges of the alluvial fans of the Kings and Kaweah Rivers. The Chino soils have a very gently sloping or nearly flat surface, interrupted by occasional low swales or old slough channels. They have been frequently flooded, each flood depositing a small quantity of fresh alluvial material on the surface, but considerable concentration of lime and clay has taken place in the subsoil. Poor drainage in the past has favored the growth of a good vegetative cover and the accumulation of organic matter within the mineral soil mass. The ground-water level now fluctuates between 5 and 20 feet, although formerly it must have been rather constantly near the surface.

The surface soil is dark gray, becoming very dark gray or nearly black when moist or wet. The lighter textured types usually are structureless but break up to a medium lumpy friable condition under cultivation, whereas the heavier textured members break into coarse clods, and the clay type has an irregular blocky structure. Secondary cracking of the larger aggregates occurs on drying, forming irregular medium to coarse clods or blocks with a firm to hard consistence. The surface soil is 6 to 18 inches thick and generally calcareous. The subsoil, normally heavier textured than the surface soil and 30 to 45 inches thick, is very dark gray and moderately compact, with a definite fine blocky structure and brittle to hard consistence. The surfaces of

the small irregular blocks are stained with colloidal coatings, and small specks and threads of white or very light gray lime and gypsum stand out in contrast with the dark surrounding soil material. Small tubular pores, the surfaces of which are often colloidal or lime-coated, are frequently encountered but do not give the soil mass much porosity. The upper subsoil grades into the lower subsoil, which is generally browner in color and has a less well-developed structure. This lower layer is somewhat compact and shows some dark-brown colloidal stains on the surface of the medium-sized structural units. The consistence is firm or brittle and usually the lime concentration is highest here, although it is less obvious than in the upper subsoil because of the lighter colored surrounding soil mass. In many places the lower subsoil is mottled with rust-brown iron stains and has about the same texture as that of the upper subsoil. The alluvial parent material is stratified, micaceous, more or less massive, and variable in texture. Its color ranges from light brown to light grayish brown and is usually mottled with rust brown.

The Chino soils have very definite surface soil and subsoil layers, and the dark lime-speckled, moderately compact irregular fine blocky upper subsoil is conspicuous. In the fine sandy loam the subsoil is not so well developed structurally and is not so compact as in other members of the series. In a few places dark layers underlying the subsoil have the appearance of old buried soil horizons. The soils are productive where not affected by concentrations of salts, but most of the areas are moderately affected. The native cover consists largely of grasses and associated herbaceous plants. These soils are related to and associated with the soils of the Foster and the Merced series, which represent younger and older stages in soil development.

TRAVER SERIES

A low flat or a hummocky relief with many old shallow stream channels between the mounds is characteristic of the Traver soils. They are developed on the outer fringes of old river fans where both surface and subsoil drainage are poor and alkali content is high. They are derived from mixed alluvial materials.

The very light-gray surface soil has a distinct light-brown cast when moist. Except for the immediate surface, which frequently is vesicular, no distinct structure occurs in the surface soil, the lower part of which is loose or firm, depending upon the moisture content. The content of organic matter is very low. The brown or grayish-brown very compact hard subsoil underlies the surface soil abruptly between depths of 5 and 12 inches. A few cracks may occur in the upper part, but the layer is usually massive. It commonly has a heavy fine sandy loam texture and is unusually compact for such a light texture. Root holes are well preserved and are lined with thin colloidal coatings. The subsoil grades into a light-brown loose and structureless fine sandy loam substratum at a depth of 15 to 20 inches. There may be some stratification, and occasionally a few small hard nodules are in the lower part. A faint rust-brown mottling is common. The soils are calcareous throughout.

Laboratory tests indicate that these soils contain a moderate quantity of alkali, but their scant cover of grass and alkali weed would indicate stronger concentrations. These soils are associated with and related to the Pond and Fresno soils and are the youngest of the three in stage

of development. They are also associated with the Chino soils, which have a darker colored surface soil and a much better vegetative cover. Where the Traver join the Chino soils the latter occupy the low flat depressional areas, whereas the Traver soils occupy low mounds of 6 to 12 inches high.

POND SERIES

Pond loam is the only type of its series mapped in this area. This soil has developed from transported mixed material, mainly of granitic origin. In its present position it is affected by a high alkali content and has poor surface and subsoil drainage. It occupies the low flat areas on the outer margin of old river fans and has a hummocky-playa microrelief.

The 3- to 9-inch light-gray surface soil is usually shallow, with a moderately hard or compact consistence and no pronounced structure except for the immediate surface layer, which in some places is vesicular or consists of a thin crust. The content of organic matter is very low. The subsoil is light gray, massive, and very compact and has developed from thin stratified layers of material of variable texture and color. The Pond series contains few roots, but root holes are well preserved and frequently lined with a thin colloidal coating, which also appears in any cracks that may occur. White segregated lime may be present in this layer, generally in the lower part. The compact subsoil is generally rather thick but below a depth of 40 to 60 inches may be underlain by gray or brownish-gray somewhat less compact structureless material. The soil profile is calcareous throughout, and black alkali is common in the subsoil.

The native vegetation consists of scattered alkali-tolerant weeds and grasses. This soil does not have a hardpan like that in the Fresno series but has a denser subsoil than in the Traver series. As mapped in this area the soil has a denser subsoil than is typical of the series.

FRESNO SERIES

The Fresno soils occupy flat poorly drained outer fringes of old alluvial fans where a high concentration of salts prevails. A microrelief of low ridges and shallow depressions is common. These soils are derived from mixed transported material having its origin mainly in granitic rock.

The light-gray or almost ashy-white surface soil is 7 to 20 inches thick, though quite variable in this respect. It usually has a massive structure, although it may be somewhat platy and the 2-inch surface layer may have a vesicular porosity. The surface layer is underlain by a gray or brownish-gray hardpan layer of a variable degree of hardness, thickness, and uniformity. Generally it has a tendency to break into platy layers, rather softly cemented by lime and silica. Pores and small voids, apparently old root holes, may be present. The underlying substratum, a loose unconsolidated material, is encountered at variable depths, depending upon the thickness of the hardpan layer. Surface drainage is poor, and because of the impervious hardpan there is little internal drainage through the soil. The alkali content is high, with black alkali nearly always present. The native vegetation consists of scattered grasses, pickleweed, saltgrass, and other alkali-tolerant plants. The soils are calcareous throughout.

These soils are adjacent to and related to the Pond series, but have a more strongly developed profile and are more impervious. They have a thick dense hardpan layer, whereas the hardpan layer occurring in other areas is more platy with loose material between the plates.

LEWIS SERIES

Lewis clay loam, the only type of its series in the county, occupies slight depressions in the valley plain and has poor surface and internal drainage. Many winding sloughs occur. The material from which it is derived consists of alluvium having its source mainly in granitic rocks.

The 4- to 7-inch surface soil is light gray or light grayish brown, becoming somewhat darker when moist. It is structureless or somewhat platy, with a brittle or crumbly consistence when dry. The upper subsoil layer extends to a depth of 10 to 14 inches and has a dark-brown distinct prismatic structure. The prisms are flat on top, 3 to 4 inches thick, and 4 to 7 inches in vertical dimension. They are less definite in the lower part of the horizon, where they grade into a second layer of irregular blocky structure. The upper subsoil material is clay, and the dark-brown color permeates the whole prism mass, but in the lower part this grades into the reddish-brown material of the lower subsoil. Roots tend to follow the cracks between the prisms of this upper subsoil layer. The second layer of the subsoil has an irregular fine blocky or coarse firm or hard granular structure, but its most striking characteristic is its reddish-brown color. Small distinct round dark stains are inside the blocks. The subsoil is very sticky when wet and hard when dry. Only a few coarse roots are present. The color of this horizon changes gradually to a light gray as it grades into the third layer of the subsoil, which is a platy to nodular, brittle, semicemented, lime hardpanlike material. The faces of the plates are mottled with rust brown. The nodules are large, are present in large numbers, and have a distinct vertical distribution as if they had formed in old root channels. The lower substratum, below a depth of 50 to 60 inches, is gray or grayish-brown loose structureless highly micaceous sand.

The surface soil is strongly calcareous and the first two layers of the subsoil contain large quantities of black alkali, which appears to be almost absent in the hardpanlike layer and the substratum. This soil is associated with and lies adjacent to the Pond and Fresno soils. A moderate growth of grass is present in spring, and the sloughways are lined with willows.

LETHENT SERIES

The Lethent series comprises grayish-brown calcareous soils developed from sandstone and shale alluvium. They occupy the broad smooth gently sloping older alluvial fans lying west of the axis of the San Joaquin Valley. Both surface and internal drainage are poor.

The 6- to 20-inch grayish-brown or light grayish-brown slightly calcareous surface soil breaks into firm or hard clods when dry. The surface soil generally grades into a brown or light-brown subsoil that is normally heavier textured, shows some evidence of profile development, and extends to a depth of 30 to 45 inches. It is moderately compact and usually has a fairly well-developed but irregular me-

dium-blocky structure and a firm or hard consistence. Lime and gypsum have accumulated and fill or line the surface of small tubular pores. Dark-brown colloidal stains are generally discernible. The underlying parent material consists of brown or light grayish-brown calcareous stratified and variable-textured material, normally loose or at least less compact than the subsoil. Accumulations of gypsum are common in the subsoil and parent material. The salt concentration is normally strong, although the salts are not of an alkaline nature.

Grasses and associated herbaceous plants make up the native vegetation except where strong concentrations of salt exist. In these areas *Atriplex* with some thin scattered grasses make up the cover. The soils are used for grazing.

SOILS OF THE VALLEY BASINS

The soils of the valley basins occupy more than one-third of the county. They range from very dark gray to light gray—the lighter colored soils occurring around the old lake margin. The parent material consists largely of fine lake sediments and river deposits derived from mixed sources but mainly from rocks of granitic character. The surface is depressional and in the Tulare Lake bed is nearly flat. These soils are often subjected to deposition of alluvial sediments by streams and flooding, and the destruction of crops often takes place during years of abnormally high rainfall and snowfall in the Sierras. The soils occurring along old beach lines of the lake margin are generally light textured and have a low moisture-holding capacity, whereas the darker colored lower lying heavy-textured soils of the old lake bottom are much superior in this respect.

These soils have a narrow range of crop adaptation, owing largely to alkali and drainage conditions. Small grains and cotton are the two main crops. The production of sugar beets is in the experimental stage. Some alfalfa and corn also are grown, but the acreage is small. The subsoils and substrata of these soils usually contain harmful amounts of alkali, and the crops grown and irrigated throughout the summer are more likely to suffer from the rise of these salts than are the grain crops that grow in winter and early in spring, when surface evaporation is low. The very heavy surface texture of some of these soils makes tillage operations difficult, and tillage can be accomplished only when soil-moisture conditions are favorable.

The soils of the valley basins are represented by the Merced, Rossi, Temple, Tulare, and Hacienda series.

MERCED SERIES

The Merced soils have a depressional relief and occur along river flood plains and in low-lying areas where moisture conditions give rise to a rank vegetative growth. They are derived largely from transported sediments of mixed but mainly of granitic origin.

The 6- to 8-inch surface soil is dark gray but is almost black when moist or wet. It is relatively high in content of organic matter. The 2- or 3-inch surface layer frequently is loose and granular or cloddy when dry, but is underlain by hard or very firm clods and lumps.

Drainage is poor throughout, and the soils are sometimes overflowed. The content of alkali is variable, but these soils are rarely

free of salts. The native vegetation consists largely of grasses, with willows and cottonwoods along the streams. The surface soil may or may not be calcareous, whereas the subsoil and substratum are always calcareous.

ROSSI SERIES

Rossi loam is the only type of its series in this area. This soil occupies the outer fringes of the Kings River fan and lies between the young Grangeville and Foster soils and the Hacienda, Merced, and Tulare soils of the valley basin. Surface and subdrainage are poor, and the seasonal water table fluctuates at shallow depths. The soil contains moderate to strong concentrations of alkali and supports a grass vegetation, with willows along the sloughs. The microrelief is very irregular with low ridges and shallow depressions.

The surface soil is dark gray, hard, and compact when dry, and except for a few cracks is structureless. Fragments of mussel and similar shells are present in places. The greenish or olive-gray clay loam or clay subsoil lies at a depth of 4 to 18 inches. When dry, vertical cracking produces an irregular blocky or prismatic structure in the upper part, but this gradually fades with increasing depth. The sides of the large blocks are coated with colloidal stains, and to some extent roots follow the cracks. Considerable coarse myceliallike lime segregations occur in old root channels. The underlying substratum, consisting of stratified layers of brownish-gray or greenish-gray material of variable texture, lies below a depth of 30 to 50 inches. Layers of lime nodules are common. Rust-brown mottling may occur both in the subsoil and substratum. The soil contains moderate quantities of salts, but very rarely is black alkali present. It is calcareous throughout. The profile varies considerably within short distances.

TEMPLE SERIES

The Temple series in this county is represented by Temple loam. This soil has developed on relatively recent alluvial deposits that have been superimposed over older materials. The surface soil and upper subsoil are intermittently calcareous and are of high organic-matter content. They are dark brownish gray or dark gray to nearly black, of low volume weight, and of friable granular character. The lower surface soil and subsoil materials are much mottled with iron stains, and the deeper subsoil is typically distinctly calcareous, with seams and in places nodules of segregated lime. The underlying material appears to be related to that of the Merced and Rossi soils. This olive-gray substratum contains much nodular lime and cemented lime carbonate pellets and becomes dull mottled gray when dry.

The surface is generally smooth but somewhat cut up by minor drainageways and old slough channels, with occasional low mounds in which the soil approaches that of the Merced and Rossi series.

TULARE SERIES

The Tulare soils occupy the bed of Tulare Lake. They are very flat and poorly drained and at one time supported a rank growth of tules, but these have now been replaced with grain and cotton fields. Formerly the lake waters fluctuated greatly, and sediments were washed

in and deposited at recurrent intervals over older material that supported a vegetative cover. The sediments were derived from both igneous and sedimentary rock sources. Fragments of shale may be found on the west side of the lake, where it borders the secondary sedimentary soils, whereas in other parts of the lake very fine mica flakes indicate material of granitic origin.

The surface soil ranges from a light-gray, gray, or light grayish-brown in the lighter textured soils to a dark gray in the heavier types. The dry soils have a pronounced gray cast but when moist they are much darker; the heavier textured soil types are almost black. The sandier members of this series are structureless and have a loose open consistence; the heavier soils have a lumpy, cloddy, or large blocky structure and under natural conditions may be very hard when dry. The dark color of the heavier soils is generally due to the accumulation of organic matter from the decay of plant residues under the influence of abnormally moist soil conditions. In extreme cases the surface soil may have a depth of 36 inches without a noticeable change in character, its average depth is about 16 inches and it is rarely less than 4 inches.

The subsoil is a transitional layer between the surface soil and the substratum. A high ground-water level makes it gray, drabbish gray, or more frequently greenish gray; on drying it is light gray. The texture is commonly a clay loam or clay, but it may include sand, depending upon local conditions of stratification. The consistence ranges from loose to plastic or sticky, and the structure from none to fine blocks or large angular or cubical soft granules with dimensions of ¼ to 1 inch. When dry, these granules are firm and separate readily. Some faint rust-brown mottling may occur in the lower part or along the channels left by small decayed roots, and occasionally some gypsum or lime may accumulate in old root channels. Although the depth and thickness of the subsoil layer has a considerable range, the substratum frequently lies at about 48 inches. This underlying material is much stratified but generally consists of a loose and open to compact and plastic heavy clay loam or a lead-gray clay mottled with rust brown. The heavier textured material may have a platy structure and becomes rather brittle when dry.

The Tulare soils are highly calcareous throughout. Fragments of shells of fresh-water mollusks are characteristically present. These soils occupy the flat shallow depression of the Tulare Lake bed, which is partly protected by levees and farmed except in years when filled with floodwaters. They occur adjacent to the Hacienda and Merced soils but have a more pervious subsoil and are more subject to flooding.

Both surface and internal drainage are very poor within the lake bed proper, the gradient being only 5 feet in a distance of 8 miles. This flat relief gives rise to problems in floodwater control and irrigation. During years of excessive snowfall in the Sierras floods along the Kings and Kern Rivers sometimes cover large areas of the lake bed despite control by a system of levees now established throughout the lake basin.

The underlying strata of this lake bed contains salts that have a tendency to move upward in dry years. This may be counteracted to some extent by holding water on the land for several months in years when water is plentiful and cheap. The old lake margin contains larger quantities of salts. The soils produce crop returns in propor-

tion to the concentration of salts present and the quantity of water available for irrigation.

The present vegetative cover of the uncultivated Tulare soils is limited to grasses, largely foxtail chess and some saltgrass. Shrubs, including *Atriplex* and pickleweed, also occur to some extent along the old lake margin, where the salt content is usually high. The entire lake bed is now farmed except when occasionally submerged by floods. The vast areas of tules that formerly flourished there are now limited to small scattered clumps in irrigation canals.

HACIENDA SERIES

The soils of the Hacienda series occur around the old margin of Tulare Lake usually above the 195-foot level. They have a comparatively flat relief with a wind-modified microrelief dominated by low ridges and mounds. The parent material consists of stratified lake deposits largely of mixed origin.

The surface soil is gray or light-gray when dry, but dull gray or brownish gray when moist. There is no definite structure and the material is loose and open. The content of organic matter is generally very low. The 5-inch surface soil (range, 4 to 12 inches) is underlain abruptly by a compact, dense, prismatic subsoil. The greenish- or olive-gray prisms have flat tops and are 2 to 4 inches in diameter and 4 to 7 inches long. Their sides are frequently stained dark with colloidal or organic matter. When dry, the cracks between the hard prisms are filled with soil material from the surface layer. The lower part of the prisms contains segregated white or tan-colored lime and gypsum, which increases in quantity in a second subsoil layer that lies at a depth of 11 to 20 inches. It has a few cracks but otherwise is massive and not so compact as the upper subsoil. The texture of both horizons ranges from a fine sandy clay loam to a clay. Underlying substrata, at an average depth of 30 inches, are stratified variable-textured greenish-gray layers containing much rust-brown mottling. These layers frequently contain hard gray angular calcareous nodules.

All the soil layers are calcareous and contain shell fragments and some mica flakes, and all except the surface soils have strong concentrations of black alkali. The native cover is largely grass and some iodine bush. The Hacienda soils are adjacent to the Merced and Tulare series but have a more strongly developed profile than the Tulare soils, to which they are closely related.

SOILS OF THE FOOTHILLS

The soils of the foothills all occur on strongly rolling or hilly areas in the southwestern part of the county. They are for the most part shallow and of little agricultural value, being used at the present time principally for grazing sheep and beef cattle. They have developed on parent bedrock that consists chiefly of calcareous sandstones or shales in variable degrees of consolidation. In many places, particularly in the Kettleman and Kreyenhagen Hills, there occur shales of gypsiferous and saline character. Because of the very low rainfall, which is insufficient to remove all of such relatively soluble salts, the soils have inherited to some extent the gypsiferous and saline char-

acter of the parent rock. Most of the soils of the Kettleman series are affected by a slight quantity of alkali.

In a southwestward direction from the Kettleman Plain toward the Coast Range Mountains, with the exception of McLure Valley, a general increase in elevation is accompanied by a small but significant increase in precipitation. The Kettleman soils, except for a few high points in the Kettleman and Kreyenhagen Hills, are generally at elevations of less than 1,000 feet. A belt of soils between 1,000 and 1,500 feet on the foothills adjacent to the rough mountainous land, however, contains not only typical Kettleman soils but also a related soil that occurs under slightly higher rainfall and is recognized as an inclusion of the Altamont series with intermediate transitional soils. The soils in this belt are closely and intricately associated with one another, and because they are at present potentially unimportant for agriculture, they are not differentiated, but mapped as soils of the Kettleman-Altamont complex.

Soils of the foothill region are of the Kettleman, Altamont, and Nacimiento series.

KETTLEMAN SERIES

The Kettleman soils are developed from calcareous sandstone and shale that in many places contain strata high in gypsum and sodium salts. In this area they occupy a rolling or hilly relief at elevations between 300 and 1,000 feet. The Kettleman soils erode easily, and although the annual precipitation is low, part of it comes in short intensive rains of cloudburst magnitude. Many places, particularly in the North Dome portion of the Kettleman Hills, are bare or have only a few inches of soil.

The 6- to 18-inch calcareous surface soil is light brownish gray. Fragments of shale are frequently scattered over the surface and through the soil. The underlying subsoil material is generally of transitional character between the surface soil and bedrock, although in some places there are small accumulations of lime. Light-gray calcareous shale or sandstone bedrock of variable degrees of consolidation lies at a depth of 10 to 40 inches. Lime generally occurs as seams or along cracks in the rock mass.

ALTAMONT SERIES

The Altamont soil, represented in the Kettleman-Altamont complex, has developed on sandstone and shale with occasional conglomerate rocks in which the embedded gravels are derived from hard sandstones, quartzite, and igneous rocks. The occurrence is in hilly to mountainous areas in which outcrop of the parent bedrock sometimes occurs. The lighter textured types are subject to both sheet erosion and gullying. Most of the erosion has been induced by overgrazing, mainly by sheep. The native vegetative cover consists of grasses with associated herbaceous plants and occasional scattered oaks. Surface and internal drainage are usually good, but a few small areas are subject to seepage.

The surface soil consists of grayish-brown or dull grayish-brown noncalcareous material, which except in the heavier textured types is moderately friable but somewhat inclined to become puddled and baked if pastured when wet. When disturbed the surface soil breaks into

irregular-shaped clods that under cultivation are reduced without great difficulty to a friable condition. The rather indistinctly blocky subsoil is slightly lighter brown, usually somewhat heavier in texture than the surface soil, and intermittently calcareous. Minor colloidal stains are developed on the surface of the soil aggregates and along root and insect holes. Gypsum crystals occasionally occur in the lower subsoil in association with segregated lime. The subsoil grades into rather soft partly weathered bedrock in which seams and encrustations of lime occur.

NACIMIENTO SERIES

The Nacimiento series, represented in the area only by Nacimiento clay, is developed from calcareous shales and occurs on a strongly rolling or hilly relief at elevations of 1,500 to 2,000 feet. This soil is related to the Kettleman series but is developed under somewhat higher rainfall and under more luxuriant grass cover. There is considerable runoff, but erosion is not severe.

The 6- to 15-inch light-brown to brown calcareous surface soil is normally heavy textured, slippery and sticky when wet, and develops an irregular firm or hard cloddy structure when dry. When worked, it has a brittle or firm cloddy tilth that breaks into a granular mass with some difficulty. The content of organic matter is not high, but grass roots, worm holes, and small tubular pores or old root holes are numerous. Although relatively permeable, the brown subsoil is generally of clay texture and moderately or slightly compact. An outstanding feature of this lower layer is the myceliallike character of white lime accumulations that fill or line the surfaces of small tubular pores. When thoroughly dry, the subsoil tends to crack into a brittle or hard cloddy mass that contains some colloidal coatings on the surfaces of the structural units. With depth the subsoil becomes lighter brown to a depth of 20 to 40 inches, where it grades into calcareous gray shale bedrock, somewhat rust-brown and yellow mottled softly consolidated and partly disintegrated and decomposed. Lime is segregated in the shale as seams or along cracks in the rock mass.

MISCELLANEOUS LAND TYPES

Riverwash and rough mountainous land are the two miscellaneous types discussed in this report.

DESCRIPTIONS OF SOIL UNITS

Chino clay.—The surface soil is a noncalcareous dark-gray clay. When allowed to dry undisturbed, large cracks form large hard blocks and clods and a so-called "adobe" structure. This vertical cracking continues into the subsoil to a depth of 12 to 18 inches. The clods of the upper dark-gray subsoil are larger and less distinct than in the loam and clay loam types, and this layer contains some segregated lime. The lower olive-gray subsoil has little structure and a considerable quantity of segregated lime. Below a depth of 50 or 60 inches a light-gray or brownish-gray light-textured substratum occurs. The alkali content is low and interferes very little with crop production. This soil is somewhat variable in profile, in some places

showing little structural profile development, in others approaching the more strongly developed Merced soils.

Chino clay occurs in three bodies totaling 7.5 square miles—two of them are near the Dallas School and the other is just east of Corcoran. The relief, although nearly flat and uniform, in places is slightly depressional; internal drainage is fairly good, however, and little accumulation of salts has occurred. During wet years the water table rises to within 5 feet or less of the surface. About 90 percent of this soil is farmed to grain or cotton, with some small fields of alfalfa. Grain yields 30 to 40 bushels an acre, and cotton about 1¼ bales. The remaining 10 percent is grazed. Although the heavy-textured surface soil has exacting requirements for tillage and will puddle badly if plowed when wet, the other general aspects for continued successful cultivation are good. Because of the high moisture-holding capacity, the generally adequate subsoil drainage, and the low salt content, alfalfa could be more generally grown if desired.

Chino clay loam.—The surface soil is a dark-gray cloddy clay loam that is difficult to cultivate. It puddles easily if plowed or pastured when too wet, especially the areas that contain large quantities of salts. The upper subsoil layer is darker than the surface soil and has a firm irregular fine blocky structure that contains spots and seams of white segregated lime. The lower subsoil is compact and somewhat dense so that it becomes almost impervious when wet, thus permitting little internal drainage. Both subsoil layers have a heavy clay loam or a clay texture and, together with the grayish-brown underlying substratum, usually contain black alkali, whereas the surface soil does not.

An area of 15.7 square miles occurs in moderate-sized areas on the outer 5- or 6-mile margin of the Kings River fan, extending from north of Stratford eastward to Corcoran. One small area occurs near Hardwick, and one is near the Delta View School and two small areas are 4 miles south of it. The general relief is flat or slightly depressional, with broad shallow meandering drainageways in the larger bodies. Consequently the surface drainage is poor, and the soil supports a grass cover that provides fair grazing. The water table is high but may drop to below 10 feet during successive dry years.

The alkali content limits its use almost wholly to grazing, two exceptions being an area 2 miles north of Dallas School and a narrow strip along the county line east of Corcoran. Both these areas lie adjacent to Chino clay and give about the same yields. Its value for grazing is less than that of Chino loam; the grass is less thrifty, and the barren alkali spots are larger. The soil is less likely to respond to cultivation than Chino loam because of normally higher alkali content, a somewhat denser subsoil, and the heavy texture of the surface soil.

Chino fine sandy loam.—This soil departs somewhat from the typical Chino soils and might be considered transitional between the Foster and Chino series. The dull or dark-gray fine sandy loam surface soil is soft and easily tilled. It contains much less organic matter than Chino loam, and it may or may not be calcareous. At a depth of 7 to 15 inches it is underlain by dark-brown or grayish-brown firm loam or clay loam subsoil containing segregated lime in pores and

old root channels. Except for a few cracks which develop when the soil dries, little structure is evident. The loose light-brown or light brownish-gray substratum lies at a depth of 20 to 40 inches, is more or less stratified, is typically light textured, and in many places is mottled with rust brown—evidence of poor drainage. Usually this soil has a spotted alkali condition. In such places a good producing field will contain areas where the good crop growth drops off abruptly to stunted poorly leaved plants or areas barren of vegetation. The severity and number of such spots varies greatly from place to place.

Chino fine sandy loam occurs in small bodies on the fans of the Kings and Kaweah Rivers. The areas are small, one of the largest occurring near the Delta View School east of Hanford. A small area 3 miles east of the northwest corner of the county has a brown loamy fine sand surface soil that is not typical of Chino fine sandy loam. Because of their limited extent, several small areas of Chino sandy loam are also included with Chino fine sandy loam. These occur mostly as long narrow strips along Mosquito and Mill Creeks. Chino fine sandy loam generally occurs farther up on the fan instead of near the outer fringes as do the other soils of the Chino series. Its general relief, however, is slightly depressional. Surface drainage is poor, the water table is usually high, and subsoil drainage is restricted. The subsoil, however, is not too heavy, or too dense to prevent downward percolation when the water table is low.

Perhaps 50 percent of the 19.6 square miles is farmed. Many of the small areas are included with fields of the better soils. The remaining 50 percent is used for pasture or contains strong concentrations of alkali and is of little use even for grazing. Where the salt content is low, alfalfa yields ¾ to 1¼ tons an acre for each cutting, and cotton produces an average of about 1 bale. A limited acreage of corn and small grains is grown on areas where the soil contains somewhat stronger concentrations of salts. Though the subsoil offers some resistance to internal drainage it can be leached of most of the harmful salts if they are not too concentrated and provided the water table is lowered. If the water table rises again, however, the salts will be redeposited in the surface soil.

Chino loam.—The surface soil is a dark-gray moderately friable lumpy or cloddy loam that is well supplied with organic matter and in most places is calcareous. Normally this layer contains less alkali than does the subsoil, the upper part of which lies below a depth of 6 to 15 inches. The upper subsoil is slightly darker than the surface soil, and it has a small firm irregular blocky structure and much lime. The lower subsoil is much more dense, compact, and brown than either the surface soil or upper subsoil. When wet the brown color largely masks the segregated lime. A brown or light grayish-brown firm underlying substratum lies below a depth of 30 to 50 inches.

An area of 33.3 square miles is mapped. It occurs in numerous small bodies throughout the area of the Kings River fan but the larger more uniform and most typical areas are in the vicinity of Cross Creek and east of the Tulare-Kings County line. The areas on the Kings River fan are for the most part small and have a slight depressional relief. They have a heavier textured compact subsoil that contains accumulated lime, but in general they do not have so strongly developed profiles as the larger areas. Normally there is little if any

surface drainage. The large quantity of water entering the soil results in a rank grass cover and adapts this soil to grazing. The subsoil, especially in those areas east of Cross Creek, is dense and compact in the lower part, and internal drainage is slow. During consecutive wet years the water table rises to near the surface, although normally it is between 10 and 20 feet.

About 20 percent of this soil is farmed. Generally, the yields are definitely lower than those for the Grangeville and Foster soils. The crops grown are largely cotton and alfalfa, with some grain and corn. The value of this soil is largely determined by its alkali content. Where the salt content is low it will produce fair cotton and good alfalfa. The latter crop is to be recommended because of its deep rooting system and because it shades the surface soil well and thus prevents excessive evaporation and the subsequent rise of alkali. In about two-thirds of the field tests made, this soil contained black alkali in the subsoil.

Chino loam and Chino clay loam are two of the better grazing soils of the area; however, the value is limited by the alkali content, the effects of which show up as small bare gray spots. Chino loam has a carrying capacity of about 60 to 90 cattle a section during the grazing season. Its grazing value might be increased by the use of permanent pasture seedings which, however, are relatively new to this county. Such pastures require frequent irrigation and alternation in use. As mapped this soil includes minor transitional variations in texture which join with areas of Chino silty clay loam of the Visalia area.

Commatti clay loam.—This soil conforms closely to the series description. The dark-brown to dark grayish-brown clay loam surface soil is 12 to 20 inches thick, and normally forms irregular firm or hard clods when dry and becomes sticky and slippery when wet. The subsoil is a slightly or moderately compact dark-brown heavy clay loam or clay that contains white lime accumulations of myceliallike form. Underlying material at a depth of 30 to 45 inches consists of brown calcareous clay loam or clay containing a smaller quantity of segregated lime, but it is nearly as compact as the subsoil.

Two small narrow bodies of the 0.8 square mile mapped are located in Stoker Canyon in the extreme southwestern part of Kings County, and one is located along the upper part of Garza Creek about 5 miles southwest of Avenal.

Commatti clay loam supports a comparatively thick cover of native grasses and is used principally for grazing, although in places a small acreage of grain is dry-farmed. It has a good moisture-holding capacity, and in years of above normal rainfall about 10 to 15 bushels of wheat are obtained, but in dry years the grain is cut green for hay.

Commatti clay loam, shallow phase.—The surface soil is a dark-brown slightly calcareous heavy clay loam that generally contains some gravel and forms friable or brittle irregular clods when dry. At a depth of 8 to 18 inches the surface soil grades into a brown or somewhat reddish-brown slightly or moderately compact gravelly clay subsoil. The subsoil normally contains some segregated lime occurring in a myceliallike form, and generally there is some colloidal coating on the surfaces of the rather indistinct structural units. At a depth of 25 to 45 inches, the subsoil rests on a light-gray or light brownish-gray gravelly substratum, which in the upper part may be

partly cemented by lime. The deeper substratum becomes browner and in places redder with depth and may overlie sandstone and shale bedrock at a depth of 5 to 20 feet or more.

Commatti clay loam, shallow phase, is used entirely for grazing; the soil supports a good growth of native grasses and herbaceous plants in spring and early summer. Of the 2.4 square miles mapped, one large and two smaller bodies occur in McLure Valley near Avenal Creek.

Dinuba sandy loam.—The surface soil is a grayish-brown noncalcareous sandy loam that in many places approaches a fine sandy loam in texture. It is porous and easily worked and readily breaks down to soft lumps or a fine-grained mass. Some coarse quartz grit and a considerable quantity of mica is distributed throughout the surface soil and the subsoil, which occurs at a depth of 10 to 20 inches. In the lower part of the loose permeable subsoil a small quantity of segregated lime may occur, and at a depth of 36 to 60 inches the subsoil rests abruptly on a gray calcareous consolidated substratum that definitely prevents further root penetration and seriously retards or arrests water movement throughout it. Owing to the depth of the subsoil, crops produced rarely suffer from a high water table. This substratum is 11 to 25 inches thick and consists of silty material that has largely become cemented to a hard mass by lime and silica. Beneath it lie layers of loose or consolidated material extending to a depth of 8 or 10 feet. The surface and subsoil appear to be material deposited in comparatively recent times.

A few small bodies occur in the extreme northeastern part of the county in close association with soils of the Grangeville series. An area of 1.7 square miles is mapped.

Like the Grangeville soils, Dinuba sandy loam is productive and is intensively cultivated to Sultanina grapes, apricots, and alfalfa. Good yields are obtained, although tree fruits do not yield so well, probably because of restricted root development caused by the cemented substratum. Some areas of this soil are affected by a spotted alkali condition, and other smaller areas are affected by moderate or strong concentrations of salts that seriously retard or prevent crop production.

Foster clay.—The surface soil is a dark-gray clay containing a fairly high content of organic matter. It is sticky and puddles easily when wet and is hard and massive when dry. The soil is worked with difficulty at any time, but is best plowed when fairly dry, breaking into large clods that are reduced to smaller lumps fairly easily. The rust-brown mottled gray clay or heavy clay loam subsoil lies at a depth of 12 to 20 inches. The underlying material, which occurs at a depth of 28 to 38 inches, generally consists of an olive-gray or brownish-gray clay or clay loam highly mottled with rust brown. In many places layers of sandy loam or sand may occur in this underlying material. Internal drainage is slow because of the heavy texture, and the soil is normally affected by a high ground-water table. This soil is normally only slightly calcareous, although in a number of places small quantities of segregated gypsum occur in the subsoil or underlying material.

Only one body, totaling 1.5 square miles, occurs in a low area just west of the Kings River near Stratford.

Grain and cotton are the chief crops grown; yields are good but are below those obtained from the Tulare soils in the lake bed region. The soil is affected by a slight content of alkali, which, however, is largely localized in the lower depths of the soil.

Foster clay loam.—The dark-gray clay loam surface soil contains a moderate or high content of organic matter. When wet the soil is somewhat sticky, and it tends to crack into an irregular cloddy mass having a firm or hard consistence when dry. Unless tilled at favorable moisture content, the soil is hard to work, and even then forms firm clods that may be broken down with some difficulty. The 12- to 20-inch subsoil consists of gray or dark-gray rust-brown mottled relatively permeable clay loam or heavy loam underlain by drab-gray or brownish-gray loamy clay material that is normally highly mottled with rust-brown stains. Layers of variable-textured material frequently occur. This soil is normally only slightly calcareous, although a few areas are noncalcareous but of moderately alkaline reaction.

This soil occurs in low-lying small basin areas mainly north of Lemoore and in the vicinity of Stratford. A fairly large body is about 2 miles west of Grangeville and another near the Empire School north of Stratford. An area of 6.5 square miles is mapped.

Foster clay loam is one of the more poorly drained soils of the Foster series, and for that reason grain and forage crops are generally grown, although in some areas cotton is grown. Sorghums cut green for silage yield 6 to 15 tons. Good fields of alfalfa yield more than 6 tons an acre, but the fields are sometimes damaged by overflow when levees of the Kings River break. Some permanent pasture is located on this soil type. It is generally affected by a slight or spotted alkali condition, but in some small places the soil is moderately or strongly affected.

Foster fine sandy loam.—The dark-gray or dark brownish-gray fine sandy loam surface soil containing a moderate quantity of organic matter is easily worked, breaking into soft lumps that are reduced readily to a soft fine granular condition. At a depth of 8 to 20 inches, a brownish-gray or grayish-brown loose subsoil occurs that is mottled with iron stains and is generally of a fine sandy loam texture. At a depth of 28 to 36 inches the underlying material consists principally of a light brownish-gray or light grayish-brown loose stratified loamy fine sand or sand highly mottled with rust brown. Frequently layers of coarse sand occur in this lower material through which groundwater movements may take place relatively rapidly. In most places this soil is calcareous, but some areas, particularly in the vicinity of the Island School and near Stratford, are only slightly calcareous or noncalcareous. Under natural conditions these low-lying areas were subjected to considerable flooding by waters of the Kings River.

This soil, totaling 35.9 square miles, occurs in a number of small scattered bodies, but most extensively north of Lemoore on the lower part of the Kings River alluvial fan and along the Kings River flood plain near Stratford. The soil is closely associated with soils of the Grangeville series, where it occupies the lower areas, and with other soils of the Foster series.

Some of the better drained and less salty areas may produce 6 to 8 tons of alfalfa, and some of it supports other forage crops that are used largely by the dairy ranches. Some orchard fruits and grapes

are also grown, but the high ground-water table generally restricts the use of the soil to shallow-rooted crops although Muscat or Alexandria grapes do well on it in certain places. Cotton yields 1 to 2 bales an acre. Much of the soil is affected by a spotted alkali condition, and in some places moderate and strong concentrations of salts occur. Foster fine sandy loam is normally a deep permeable productive soil, but low yields are generally obtained in areas affected by alkali accumulation and a high ground-water table.

Foster loam.—The 8- to 18-inch surface soil is a dark brownish-gray or dark-gray loam generally containing a moderate quantity of organic matter that gives the surface soil its dark color. The soil is easily worked and breaks into firm moderate lumps, which break with some pressure to a granular mass. The surface soil grades into a gray or dark grayish-brown permeable heavy fine sandy loam, loam, or clay loam subsoil that is normally mottled with rust brown and that grades into underlying material at a depth of 26 to 40 inches. This material consists of relatively permeable loam or clay loam highly mottled with iron stains, although in a few places layers of fine sandy loam or loose sand occur. This loam is generally calcareous but some areas, particularly those in the vicinity of Stratford and northwest of Lemoore, are only intermittently calcareous or noncalcareous.

This soil occurs in a number of small- and medium-sized bodies scattered on the Kings River delta in a zone that lies just north of Hanford and extends from a point 2 miles north of the Excelsior School southwestward a short distance past Lemoore. It also occurs rather extensively on the lower Kings River flood plain near Stratford. The soil occupies small depressional or lower lying areas in close association with soils of the Grangeville series or with Foster fine sandy loam, but where associated with the heavier textured soils of the Foster series it generally lies at slightly higher elevations. In the vicinity of and northeast from the Kings River School a few bodies occur that have a browner surface color than is typical. An area of 26.2 square miles is mapped.

On the upper part of the Kings River delta, this soil is intensively cultivated in conjunction with the Grangeville soils and Foster fine sandy loam. Yields of orchard fruits are only fair because the prevailingly high fluctuating ground-water level is a constant threat to deep-rooted orchard trees. Plums, however, are fairly resistant to the high water table, and some good plum orchards are located on this soil. The soil is not particularly well suited to Sultanina grapes, but it is one of the best for Muscat or Alexandria grapes and yields from 4 to 8 tons. Lower down on the alluvial fan, where the soil is associated more extensively with other Foster soils and the ground-water level is higher, the soil is generally used for alfalfa and other forage crops in connection with dairying. Alfalfa commonly yields more than 1 ton a cutting to the acre, and in some places cotton yields 1 to 2 bales. Most of the soil is affected by spotted alkali condition, although there are some areas where moderate or strong salt concentrations exist.

Foster sandy loam.—Generally this soil occupies slightly higher ground in the lowland areas and represents in most places the most

recent accumulation of Foster soil material. The 10- to 18-inch dark-gray to dark brownish-gray surface soil contains a moderate quantity of organic material and is dominantly of a sandy loam texture, but includes in some places, variations approaching a loamy sand. The soil is easily worked into soft lumps or breaks down readily to a fine-grained mass. Underlying material consists of grayish-brown loose sandy loam or loamy sand mottled with rust brown and continuing to a depth of 6 feet or more. The soil in many places is only slightly calcareous.

A number of very small widely distributed bodies occur on the Kings River fan, and to some extent in the extreme eastern part of the county. Areas of moderate size occur in the vicinity of Stratford and the Crescent School near Fresno Slough in the northwestern part. A few small areas occur along the Kings River flood plain extending southward from the San Jose School. A total of 8.2 square miles is mapped.

Foster sandy loam is cultivated largely in conjunction with other soils of the Foster or the Grangeville series. Alfalfa and other forage crops are generally grown with fair to good success, and cotton is grown in some places. Most of the soil is affected by a slight or spotted alkali condition, although some areas may be affected by moderate or strong salt concentrations.

Fresno fine sandy loam.—The light-gray compact fine sandy loam surface soil has a brown cast when moist. During the summer it may become loose and puffy, whereas in the low playas where water has stood until evaporated the topmost 1½ inches is cracked and below this it is dense and hard. Like other members of the Fresno series, this soil typically has a lime-silica hardpan and a comparatively loose substratum. Like the Pond and Traver soils it is high in alkali content and is used only for grazing for which it gives poor returns.

The most typical area of the 8.4 square miles mapped lies 2 miles north of the Delta View School along the east county line. The remaining areas occur west of this area for a distance of 3 miles and north along the county line to a point 2 miles south of the northeast corner of Kings County. Most of the areas join with the Fresno soils mapped in the Visalia area (*27*). Those areas lying west and north of Cross Creek vary somewhat from the typical in that the hardpan lies deeper than normal and is generally below depths of 45 to 65 inches. These areas have apparently received considerable surface deposition from higher points on the fan. In addition to this, the hardpan, which is of a bluish-gray color, is considerably softer and does not have the hard brittle resistant character of the typical Fresno hardpan of this area. The immediate surface of the hardpan and the larger root holes are coated with a thin hard scaly lime carbonate layer. The hardpan is normally thick and comparatively impervious to moisture penetration so that this area would be no more suitable for reclamation than the other Fresno soils. Within this area, however, are many old stream channels and small elongated ridges that are not underlain by the hardpan or in which it lies at such depths as to be of no agricultural significance. Such areas where large enough to be separated are mapped as members of the Grangeville series, but where of very small extent they were included with Fresno fine sandy loam.

The typical relief is characterized by low irregular mounds separated by meandering shallow stream channels that occasionally widen out to form oval shallow ponds or playas. The position of this soil on the outer nearly flat fringes of alluvial fans causes it to have very poor surface drainage, and the impervious hardpan effectively prevents most subsoil drainage. The alkali content is high, black alkali being usually present. The natural vegetation consists of a thin cover of saltgrass and alkali weeds and shrubs. The grazing value is low except during the rainy season when the vegetation is young and tender.

Because of the thickness and density of the hardpan layer in this soil, the high alkali content, and the very poor surface drainage, attempts to reclaim this soil are not recommended.

Fresno loam.—The surface soil is considerably more compact than that of Fresno fine sandy loam. The hardpan layer occurs at an average depth of about 30 inches. In contrast to the fine sandy loam type, the hardpan is likely to consist of thin plates or lens with less dense or hard material between the plates. The texture is heavy, however, and when moist the pore space is reduced to such an extent that water will not penetrate the soil. As mapped this soil includes small undifferentiated areas of Fresno clay loam.

An area of 1.8 square miles of this soil is mapped and most of it is in the northeastern part of the county. The surface is nearly flat with barren playalike or shallow pondlike depressions, so that drainage waters gather on the surface and are removed mainly by evaporation. This results in large concentrations of alkali, with the result that vegetation is very sparse. The grazing value is extremely low, about equal to that of Pond loam.

Grangeville fine sandy loam.—The 9- to 18-inch grayish-brown to brown or light-brown surface soil is a calcareous fine sandy loam that is easily worked to a friable lumpy tilth and breaks readily to a loose single-grained mass. The subsoil is a permeable loose calcareous light-brown or grayish-brown fine sandy loam generally containing some streaks and spots of rust-brown mottling. This is underlain at a depth of 30 to 45 inches by mottled loose calcareous light-brown or light brownish-gray stratified fine sandy loam or loamy fine sand. In places layers of loose coarse sand occur in this underlying material, and these lower the water-holding capacity of the soil considerably and make more frequent surface irrigations necessary. Crop production may be considerably lower where it is underlain by such porous material, but such areas are generally so small and stratification so irregular that it is impracticable to show them on the soil map.

This soil is the most important in the county, and grows much of the intensively cultivated grapes, orchard fruits, alfalfa, and cotton crops of the county. The soil occurs extensively in many large and small bodies, totaling 117.6 square miles, scattered over the Kings River delta in close association with the soils of the Foster series and other soils of the Grangeville series. In some places near Cross Creek northeast of Lakeside School, where the soil is associated with some of the Chino soils, there occurs at a depth of 42 to 60 inches, a dark-colored slightly compact layer that has many characteristics of the subsoils of the Chino series. Such a condition was probably

brought about by an overwash of Grangeville fine sandy loam material on some member of the Chino series. In the extreme northeastern part of the county, where the soil is associated with Dinuba sandy loam, there are a few places where the soil overlies a consolidated substratum at a depth of 60 inches or more. Outside of these exceptions and the slight gradations of color that occur where associated with soils of the Foster series, Grangeville fine sandy loam is typical of the Grangeville series.

Most of this soil produces 4 to 7 tons an acre of Sultanina (Thompson Seedless) grapes, whereas the yields of Muscat of Alexandria grapes are somewhat lower. A large percentage of the apricots and peaches are grown on this soil. The apricots yield 3 to 6 tons and the peaches 4 to 7 tons an acre. Some plums are also grown, and practically all the walnuts produced are grown as fence-row plantings. Alfalfa yields an average of about 1 ton an acre for each cutting, and cotton 1 to 2 bales. The best yields from cotton are produced during the first 3 years of planting, and after that the production declines rapidly unless some rotation is practiced. In many places there is a dangerously high fluctuating ground-water level, which recently was an important contributing factor to the death of a number of apricot, peach, and plum trees. Large areas of the soil are affected by a spotted alkali condition, and generally where low yields occur it is because of variable concentrations of salts in the soil. Much of the soil extending in a southward, crescent-shaped band from Lemoore to a few miles southeast of Hanford is affected by moderate and strong concentrations of alkali, and poor yields are obtained on the areas that are cultivated. Grangeville fine sandy loam is a deep permeable productive soil, and alkali reclamation would be possible if the ground-water level could be maintained at lower depths.

Grangeville fine sandy loam, hummocky phase.—The brown or grayish-brown calcareous fine sandy loam surface soil is loose and easily worked and readily breaks into soft lumps or a single-grained mass. The 6- to 8-inch subsoil consists of a brown or grayish-brown calcareous fine sandy loam mottled with iron stains. It is slightly compact, and white or very light-gray specks and spots of soft segregated lime and gypsum generally occur throughout the layer. The subsoil normally extends to a depth of 34 to 42 inches, where it grades into fairly loose mottled stratified calcareous brownish-gray or brown fine sandy loam or loamy fine sand that in places contains a few small hard calcareous brown nodules.

This soil occurs North of Stratford and east of the Empire School. This soil has an uneven hummocky surface microrelief formed largely through stream and wind action. Another body of this soil occurs 2½ miles west and 1 mile north of New Home School. This phase is not quite typical of the Grangeville series, for in many places the subsoil is slightly compact, but is not sufficiently so to affect root or moisture penetration. A total of 3.5 square miles is mapped.

Much of this soil is uniformly affected by very strong alkali accumulations, but where only a spotted condition exists some alfalfa and grain are grown with fair success.

Grangeville loamy fine sand.—The 10- to 24-inch normally slightly calcareous grayish-brown to light-brown surface soil is generally a loamy fine sand, although in places it is nearly a loamy sand. The

soil is loose and single-grained and offers few tillage problems. The underlying material consists of loose variable light-textured stratified material that is generally mottled with rust brown, particularly in the lower depths. Frequently layers of loose coarse sand occur in this underlying material and further reduce the low moisture-holding capacity of the soil. Because the soil is generally located on slightly higher ground, much of it has been scraped in leveling operations necessary for proper irrigation practices, and in many places a strip of it may be observed extending through a body of Grangeville fine sandy loam with both soils now at the same elevation.

This soil occurs in a number of small- and medium-sized bodies, totaling 39.4 square miles, that generally lie at slightly higher elevations than the surrounding soil and that represent, for the most part, remnants of small stream-bank ridges. In the extreme northeastern part of the area where the soil is associated with Dinuba sandy loam, there are a few places where the soil overlies a consolidated substratum at a depth of 60 inches or more. Outside of this exception and a few gradations in color where associated with soils of the Foster series, this soil conforms to the Grangeville series.

Where the soil is underlain by layers of loose coarse sand, production is generally low, but normally Sultanina grapes yield from 4 to 5 tons an acre. Muscat of Alexandria grapes are not grown on this soil. Apricots and peaches produce slightly lower yields here than on Grangeville fine sandy loam. Cotton produces 400 to 500 pounds an acre and requires more than four irrigations a season. Some alfalfa is also grown, but the water requirements are usually high. Few areas are moderately or strongly affected by alkali, most of the soil being free of any harmful salt concentrations or only slightly affected by a spotted condition. It is generally associated with soils of the Foster series or with other soils of the Grangeville series, and two small transitional areas in the northeastern corner of the county join with the related Tujunga sand of the Visalia area. It is less seriously affected by a high ground-water level.

Grangeville sandy loam.—The surface soil is a brown or light-brown slightly calcareous or moderately calcareous sandy loam that in places approaches a loamy sand. Generally a large quantity of angular quartz grit and mica flakes occurs throughout the mass. It is easily worked and breaks readily into soft lumps or a fine-grained mass. The 6- to 20-inch subsoil consists for the most part of loose permeable light-brown or light brownish-gray calcareous sandy loam that is somewhat mottled with rust brown. The underlying material, which occurs at a depth of 30 to 45 inches, is loose stratified loamy sand, sandy loam, or sand. The soil is of low water-holding capacity, and irrigation water generally has to be applied more often than on Grangeville fine sandy loam.

This soil occurs in small widely distributed bodies totaling 4.3 square miles; mostly on the eastern side of the Kings River delta and on the western part of the Kaweah alluvial fan in the extreme eastern part of the county. In the northeastern corner, where the soil is associated with Dinuba sandy loam, there are a few places where the soil overlies a consolidated substratum at a depth of 60 inches or more, but otherwise the soil conforms to the Grangeville series.

This soil type is most often cultivated in conjunction with Grangeville fine sandy loam. Yields are fair or good but not normally so

good as those obtained from Grangeville fine sandy loam. Northeast of the Excelsior School, where a narrow strip runs through a body of Traver fine sandy loam, crop production is limited to this soil with its less serious alkali conditions. Most of the soil is affected by a spotted alkali accumulation, but some areas are affected by moderate or strong concentrations.

Small areas of transitional character join with the closely related Cajon and Tujunga soils of the Visalia area into which they grade.

Hacienda fine sandy loam.—This soil is the most representative soil type of this series and closely follows the series description. The light-gray loose fine sandy loam surface soil is very low in content of organic matter and rests abruptly on the hard prismatic layer of the upper subsoil. The prisms of this layer have a sandy clay loam texture and are dark gray on the surface whereas their interior is an olive gray. The upper subsoil is underlain at a depth of 12 to 20 inches by a greenish-gray structureless clay loam layer containing segregated lime and gypsum. The underlying substratum is a variable-textured stratified layer containing hard lime carbonate nodules. The surface soil contains little salts, but the subsoil layers and substratum are very high in black alkali. The general surface is flat but has a microrelief of small wind-modified ridges and mounds. As mapped this soil includes small undifferentiated areas of very fine sandy loam texture.

An area of 18.2 square miles is mapped. The largest and most typical area lies in the vicinity of the Hacienda Ranch and several bodies occupy low narrow strips south of Dudley Ridge. One small area is located just west of the Malga Irrigation District Reservoirs. The native cover consists of pickleweed and a short thin growth of grasses. This soil is not farmed and has a very low grazing value. During years of heavy rainfall the grass is somewhat better but is still poor compared to that normally found on the Panoche soils.

Hacienda fine sandy loam, deep phase.—The gray or light-gray surface soil is a porous structureless fine sandy loam that breaks into a soft lumpy condition when tilled. It is very low in content of organic matter and has a low moisture-holding capacity. The subsoil is encountered at a depth of 12 to 30 inches. It has an olive-gray or gray color and is a rather compact loam or clay loam. The subsoil of this phase is unlike the subsoil of the normal Hacienda soils having no consistent structure except for an occasional crack. Large quantities of segregated lime and gypsum are present, and the content of black alkali is normally quite high. The gray or grayish-brown variable-textured stratified substratum lies below a depth of 25 to 45 inches. This phase is calcareous throughout, and fragments of shells occur frequently.

An area of 24.5 square miles occurs largely within a strip 4 miles wide and extends from Corcoran to Stratford. Other areas are also located north of Stratford. Near the siding at Bean north of Corcoran and in small spots throughout this soil where the surface soil is less than 10 inches deep, vertical cracking or a feebly developed prismatic structure seems to be developing. The large area north of Corcoran has a more dense and compact subsoil than is common to the other areas mapped. Less than 10 percent of this soil is cultivated, and this occurs largely in

the vicinity of Stratford where dairy farms have small fields of grain or alfalfa. Yields are low. The rest of this soil is used for grazing, and its value is low. Saltgrass is the chief cover, but lesser acreages of other grasses and some pickleweed is present. The low fertility of the surface soil and the usual large quantities of alkali present in the subsoil layers do not adapt this soil to purposes other than grazing.

Hacienda loamy sand.—The dull-gray or grayish-brown loose loamy sand surface soil is very low in content of organic matter and has a poor moisture-holding capacity. The subsoil generally occurs abruptly at a depth of 4 to 12 inches. It has a much less distinct prismatic structure than that of the Hacienda fine sandy loam, and the vertical cracking is absent in many places. The sandy clay loam or clay texture subsoil is very hard when dry but is plastic and sticky when moist. Accumulated lime in seams and old root channels continues down into the substratum, which lies at a depth of 30 to 45 inches. The substratum consists of stratified sediments derived from a variety of rocks. The soil is calcareous throughout, and though there is little alkali in the surface soil the subsoil and substratum are usually highly charged with black alkali. Fragments of mussel shells are common.

The largest area is near Corcoran, but smaller bodies are associated with Tulare clay loam from a point 6 miles south of Corcoran northwestward to Stratford. Although the agricultural value of this soil is very low, perhaps 20 percent of the 12.1 square miles mapped was farmed to cotton in 1936 and 1937. The cultivated areas were confined to small fields in the areas at Corcoran. It is doubtful that cultivation of this soil as a long-time proposition will be very successful because of the low fertility of the surface soil and the strong concentrations of black alkali present in the subsoil. The natural cover is confined to thinly scattered saltgrass and associated grasses and plants. Included with this soil type are small undifferentiated areas having a sandy loam surface soil. They are of small extent and in general are long narrow strips between Tulare clay loam and the typical Hacienda loamy sand. In many places these soils are included and farmed with fields of Tulare clay loam.

Hacienda loamy sand, deep phase.—The gray or light-gray loose structureless surface soil extending to a depth of 10 to 20 inches is very low in organic-matter content and has a poor moisture-holding capacity. Plant nutrients are low. The olive-gray loam or clay loam subsoil is firm but not extremely compact or dense. It contains segregated lime in old root channels, which continue downward into the substratum. The subsoil has no consistent structure, and the substratum, at a depth of 30 to 45 inches, is a variable-textured stratified layer. The surface soil for the most part is free of alkali, but in many places the subsoil contains large quantities.

An area of 6.2 square miles of this soil is mapped. A small area lies 1 mile northwest of Corcoran, another is at Stratford, and the two largest areas are southeast of Stratford. Small areas of loamy fine sand are included within these last two areas. This soil is used entirely for grazing. Unsuccessful attempts have been made to cultivate the larger areas. The grass cover is sparse, and, because of the droughty nature of the soil, the grasses dry up quickly after the last spring rains.

Kettleman-Altamont complex.—This complex consists of a relatively intimate association of soils of the Kettleman series with related soils of the Altamont and Nacimiento series that do not occur in sufficiently large or distinct bodies to be individually mapped. Minor differences in relief have played an important part in the development of different soil characteristics in the complex. The Kettleman soils occur generally on slopes of southern exposure and on tops of knolls, ridges, and hills where the slopes are convex and water runoff is most rapid. In most places the Kettleman surface soil is of loam texture, but in other places it ranges in texture from a fine sandy loam to a heavy loam. Darker brown clay loam and clay soils occur generally in the more moist swales and on concave slopes that extend far up the north slopes and are subject to runoff from the higher areas. The clay loam is fairly typical of the Nacimiento soil and the clay is more like the Altamont soil. These darker soils are not entirely developed from residual material, for some fine-textured soil material has been slowly washed onto these lower lying areas from above. The surface soil is noncalcareous, probably because enough rain water penetrates the soil to leach the lime into the lower subsoil. When wet the surface soil is sticky and slippery, and when dry large cracks extend downward well into the subsoil, which occurs at a depth of 10 to 20 inches. Generally the subsoil is brown clay; in the lower part it is normally calcareous, and at a depth of 30 to 50 inches it rests on a gray calcareous shale bedrock.

This soil complex, totaling 27.7 square miles, exists in a belt at the base of the steep, rough mountainous land and occurs at elevations generally between 1,000 and 1,500 feet on strongly rolling or hilly relief with a gradient of 10 to 30 percent (pl. 3, *A*). Soil color grades considerably in this soil complex. The Kettleman soils grade from light brownish gray to grayish brown and light brown, and the darker soils grade from very dark brown to dark brown and brown.

Compared to the Kettleman soils, the Altamont and Nacimiento soils are higher in content of organic matter and support a more luxuriant growth of native grasses that stay green later in the season. The soils of the complex are used chiefly for grazing, although in a few small places the darker soils are utilized for dry-farmed grain, which is rarely harvested for grain but is cut green for hay or is pastured.

Owing to the rough relief and to the limited use of the land no attempt is made in mapping this soil to differentiate the several wide variations in texture and soil profile included with this soil. These are mainly transitional in character. This complex joins with an inclusion of Hugo sandy loam of the Paso Robles area, which is representative of neither soil type.

Kettleman loam.—Typically, the brownish-gray or light brownish-gray calcareous loam surface soil of friable or soft consistence and granular structure is 6 to 18 inches thick. In a number of places there are a few shale fragments scattered on the surface. The light brownish-gray calcareous subsoil is, in most places, a transitional layer between the surface soil and the underlying bedrock. Fragments of parent rock normally are more plentiful in the lower part. This transitional or subsoil layer, however, may have some segregated lime and accumulations of gypsum which are indicative of a slight subsoil develop-

ment. At a depth of 10 to 40 inches the subsoil grades into a light-gray calcareous sandstone or shale bedrock of variable degrees of consolidation. Lime generally occurs as seams or along cracks in the rock mass. Shale rock forms the parent material of the soil in most places, but there are a number of scattered areas where sandstone strata occur near the surface, and in these areas the surface soil texture is generally lighter than typical, being nearly a fine sandy loam.

This soil occurs extensively (139.0 square miles) on the Kettleman Hills and just southwest of the Kettleman Plain on the Kreyenhagen Hills. It occupies strongly rolling or hilly land with slopes of 10 to 30 percent. Within these hills there are a few small isolated depositional areas where Panoche loam or fine sandy loam occur, but because of their small size, these bodies of alluvial soil are not shown on the soil map.

Kettleman loam is uncultivated, but it supports a sparse cover composed principally of native grasses and occasionally some *Atriplex*. Grazing by sheep and beef cattle is the only agricultural use made of the soil, and in the North Dome portion of the Kettleman Hills, where erosion has prevented the maintenance of any soil material or soil of only slight depth, the grass cover is very scattered and grazing value is low. Outcrop of parent bedrock in the more severely eroded or shallow areas is frequent. Kettleman loam is affected by a slight content of inherent alkali.

Lethent silty clay loam.—The color and other characteristics of the surface soil, subsoil, and substratum of this soil are given in the description of the Lethent series of which this soil type is closely representative. The surface soil puddles badly and is sticky when wet. Travel over this soil is very difficult during the rainy season except on surfaced roads. A low content of organic matter is present, and the roots of the *Atriplex* penetrate the soil deeply. The soil has a good moisture-holding capacity, although the strong winds common to this part of the county during late spring quickly dry the surface soil, causing it to crack and the shallow-rooted grass cover to die down for want of moisture. The subsoil and substratum retain some moisture practically all summer. Strong concentrations of salts occur in most places, and the salts are well distributed throughout the soil and subsoil.

Lethent silty clay loam occurs just west of the valley floor from Kettleman City to the northern boundaries of the county. One small body is located in the Kettleman Plains just west of Avenal Gap, and another is in McLure Valley. A total of 96.5 square miles is mapped. It represents the most eastward extension of soils derived from alluvial material of sedimentary rock origin and occupies the same relative position and has the same poor surface drainage as the Traver, Pond, and Fresno soils on the east side of the valley trough.

The native cover consists largely of grasses with *Atriplex* in the areas of the higher alkali content near the margin of the lake bed. The young tender growth of this shrub has some feed value during spring. At this time also the grasses attain their maximum value for grazing.

The heavy texture of both surface and subsoil results in slow and very poor internal drainage, and this, together with the poor surface drainage and the normally high alkali content, would make this soil very difficult to reclaim even if a supply of good water for flooding

could be obtained. Water in the wells for watering livestock is quite salty and generally unsuited to human consumption. Grazing is the best use that can be made of this soil, though in areas where the salt content is too high the grass cover is very sparse and poor.

Lethent silty clay loam, hummocky phase.—The surface soil is variable in texture from place to place. Fine sand from the lighter textured members of the nearby Panoche and Lost Hills soils has been blown over the Lethent silty clay loam surface soil forming low mounds, which in most places rise about 10 inches or less above the general surrounding level. The mounds or hummocks are irregularly spaced. Between the scattered mounds the original silty clay loam surface soil is frequently exposed and supports a poor grass cover or is barren. Some of the larger areas support some *Atriplex.* In all respects, except for this surface alteration, this soil closely resembles the normal soil.

Areas of the 16.4 square miles mapped generally occur adjacent to the normal soil west of the valley trough. This phase generally has a lower grazing value than Lethent silty clay loam. The low moisture-holding capacity of the fine sand mounds and the wind-swept character of the intermound areas do not promote growth of grasses. The alkali content of the heavy-textured material is high.

Lewis clay loam.—This soil is representative as to color and character of surface, subsoil, and substratum of the Lewis series as previously described. The surface soil has a hard consistence when dry and puddles badly when wet. Plant roots penetrate the surface soil, but they tend to follow the cracks of the upper subsoil, and only a few of the larger find their way into the second layer of the subsoil. This soil consistently contains more black alkali than any other soil mapped in this area, but because of its position in the trough of the Cross Creek flood plain it receives more moisture during spring than the adjoining Fresno and Traver soils. This added moisture lessens the effectiveness of the salts present, and, as a result, a somewhat better grass cover furnishes better grazing during early summer than the vegetation of the Fresno or Traver soils. Attempts have been made to farm this soil but accumulation of salts on the surface has greatly impaired the value of the soil even for pasture. The alkali is present in such quantity and the subsoil is of such impervious nature that reclamation by present methods is not economically feasible.

One body, 5.3 square miles in extent, is mapped along the flood plain of Cross Creek where it enters Kings County from Tulare County. The area is traversed with sloughs, and back from these channels for a distance of about 30 feet on either side the surface soil is darker than normal. These darker areas contain less alkali and support a heavier vegetative cover than do the areas farther away from the channels. The southern part of the soil area merges with and is similar to the Chino soils. Willows border the stream channels. Because of alkali, poor drainage, and impervious subsoil, this soil is suitable only for grazing.

Lost Hills clay loam.—The surface soil is brown or grayish-brown slightly calcareous heavy clay loam that cracks into irregular firm or hard clods on drying. At a depth of 6 to 14 inches, the surface soil rests on a brown moderately compact clay subsoil. This subsoil generally has a firm or hard irregular fine-blocky structure, the units of

A, View looking west over hilly and mountainous part of the county: Soils are mainly of the Altamont and Kettleman series, and rough mountainous land is in the distance. *B*, Dairy herd on pasture of Traver fine sandy loam. Soils of the Traver series contain more or less alkali salts and are of low value for crops but furnish some grazing for dairy and beef cattle.

which are usually stained dark at the surfaces by colloids. Segregated lime, following along old root holes or tubular pores and along the cracks of the mass, generally occurs in the lower part of the subsoil. The underlying material usually occurs at a depth of 30 to 42 inches and consists of light-brown calcareous relatively permeable and friable clay loam or heavy clay loam.

This soil occurs in the bottom of the Kettleman Plain and as a small body on the west side of McLure Valley. In most places the soil occupies a very gently sloping smooth relief, but in the McLure Valley the soil has an undulating microrelief that approaches hogwallowlike character. A total of 6.1 square miles is mapped.

A little grain is dry-farmed on this soil, and areas have been irrigated in seasons of unusual water supply, but by far the most of it is used for grazing purposes. The surface soil has a good water-holding capacity, but the heavy compact subsoils would retard moisture and root penetration if this soil were intensively cultivated and irrigated. Most of this soil contains some alkali, although the body in the McLure Valley is free of any injurious concentrations of salts. The soil supports a cover made up principally of native grasses, but in some places *Atriplex* makes up part of the cover.

Lost Hills fine sandy loam.—This soil is a typical representative of the Lost Hills series. The 10- to 20-inch surface soil is only slightly calcareous. It is dominantly a light grayish-brown or light yellowish-brown fine sandy loam that is easily worked to a good tilth. Small areas of slightly lighter or heavier textured soil are included. Only an inch or two of transitional material lies between the surface soil and a compact light-brown subsoil that ranges in texture from a heavy loam to a sandy clay loam. The upper subsoil is generally more or less massive and structureless, but the lower subsoil has a well-developed small blocky structure that is definitely stained with colloids and contains a relatively high quantity of white segregated lime that to some extent coats the structural units. The subsoil extends to a depth of 35 to 50 inches, and the underlying material consists of a light-gray or light brownish-gray loose permeable calcareous fine sandy loam or fine sand. In some places this underlying material may contain a layer of somewhat compact and heavier textured material with some segregated lime, which has the appearance of an old buried subsoil layer.

A number of small and large bodies, totaling 32.8 square miles, occurs along the eastern base of the Kettleman Hills south of Dudley Ridge, and along the western edges of the southern part of the Kettleman Plain. It has a gently sloping relief and in some places a slightly undulating microrelief.

Only a small area of Lost Hills fine sandy loam is cultivated, mainly because of a lack of irrigation water. The cultivated area is used for dry-farmed grain near Avenal. If it were intensively cultivated the compact subsoils would probably restrict root and moisture penetration and affect crop production. The soil supports a cover of native grasses and other plants that flourish for a few months in spring and early summer and afford some grazing for sheep and beef cattle. Most areas are affected by slight concentrations of alkali, and areas located south of Dudley Ridge are affected by moderate salt concentrations where *Atriplex* makes up a large part of the native vegetation.

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Lost Hills loamy fine sand.—The surface soil is light grayish-brown slightly calcareous loose loamy fine sand that overlies, at a depth of 14 to 25 inches, a moderately compact heavy fine sandy loam or loam subsoil. Lime accumulations normally occur in the subsoil, and generally there is some colloidal staining along cracks. Deeper underlying material occurs at a depth of 35 to 50 inches and consists, for the most part, of loose loamy fine sand or fine sandy loam. In some places, however, a layer of somewhat compact and slightly heavier textured material containing some segregated lime occurs that has the appearance of an old buried subsoil layer.

This soil occurs in a few small and medium-sized bodies southeast of Kettleman City and just south of Dudley Ridge. In some places south of Dudley Ridge a slightly undulating microrelief has been developed by wind movement of the sandy material, but otherwise the soil has a smooth sloping relief and profile representative of the Lost Hills series. An area of 3.8 square miles is mapped.

Lost Hills loamy fine sand is not cultivated; the surface soil has a low moisture-holding capacity, and the compactness of the subsoil would tend to retard root and moisture penetration if this soil were intensely cultivated and irrigated. The soil is used entirely for grazing; the vegetative cover consists of native grasses and small associated plants and occasionally some *Atriplex*. The bodies southeast of Kettleman City are only slightly affected by alkali, but the areas south of Dudley Ridge are affected by moderate concentrations of salts.

Merced adobe clay.—The 10- to 20-inch surface layer has a very dark-gray heavy clay surface soil that develops a pronounced blocky structure when dry, and this structure may be covered with a loose open coarse granular mulch layer. The surface soil is intermittently calcareous. The subsoil is not so distinct as in the more typical Merced soils; instead it contains irregular cracks and considerably less segregated lime. In the lower part it grades from dark-gray to greenish-gray color and overlies a variable-textured brownish-gray substratum at a depth of 30 to 60 inches. In places the lower subsoil contains white segregated lime-carbonate nodules.

An area of 7.1 square miles occurs in the county. All the soil areas lie in the bottom of the Kings River flood plain west and north of Stratford. Practically all of it is covered by floodwaters during wet seasons, and its normally high water table allows only very poor internal drainage. The large area lying 5 miles north of Stratford is much dissected by old channels, with the result that the soil of this area is more variable than normal.

A large part of this soil is normally used for grazing purposes. Some dry-farmed grain is occasionally planted if seasonal conditions are favorable, and some grain is grown in the area west of Stratford, which is irrigated by ditch water and is free of the dissecting sloughways common to the other areas. The rank cover of grasses supported by this soil makes it valuable for grazing purposes, but its value for production of field crops is limited by its heavy texture and poor drainage.

Merced clay loam.—The surface soil of this type is well supplied with organic matter and breaks into a friable granular condition when cultivated at favorable moisture content. Of the Merced soil types

mapped in this area the clay loam is the most representative of the Merced series. The 6- to 15-inch surface layer usually contains but little alkali, whereas the subsoil and substratum contain larger concentrations. The heavy-textured subsoil has an irregular hard blocky or slightly prismatic structure. The upper subsoil has a darker color than the surface soil, but this color changes gradually to a gray or olive gray in the lower subsoil. Considerable quantities of white segregated lime and gypsum fill root holes and pores in the subsoil. The substratum is a variable-textured gray material with rust-brown mottlings. Both it and the lower subsoil may contain small hard gray calcareous nodules. Though this soil in most places is calcareous throughout, the surface soil in some places contains lime only intermittently or irregularly.

This soil (15.6 square miles) is most typical in the vicinity of the Hacienda Ranch. Other areas located along the Kings River sloughway west and north of Stratford to the county line are very much cut by old channels and are subject to annual flooding with some deposition; all of which retarded their agricultural development under natural conditions. The depressional relief gives poor surface drainage, and subsoil drainage is retarded by a high water table. Areas are still subject to overflow during spring and early summer where not effectively protected by levees.

Somewhat less than 50 percent of this soil is cultivated, and cultivation is limited to seasons following flooding when a preirrigation by means of controlled floodwaters is possible. Except the area in the northwest corner of the county, no wells for irrigation purposes have been developed and for this reason grain that requires no summer irrigation is the main crop. A small acreage of cotton is grown, however, and the average yield is less than 1 bale an acre. An average yield of barley is about 50 bushels. Wheat gives poor returns because of the insufficient water supply. The uncultivated areas afford good pasture and remain green later in the season than the better drained areas of other soils. Saltgrass and other water-tolerant grasses and weeds make up most of the cover. Cockleburs flourish late in summer and in fall. The capabilities are limited largely by content of salts and drainage and irrigation problems.

Merced loam.—The surface soil of Merced loam is a very dark-gray loam in most places, but along its north border where it joins Tulare fine sandy loam and Tulare fine sand, beach phase, the surface texture is a light-colored and light-textured loam, as wind has blown sand from the adjacent soils onto Merced loam. A strip about a quarter of a mile wide has been affected in this manner. When cultivated this soil has a granular tilth. The subsoil is more compact and has less structure than does Merced clay loam. In land use, management, and yields it is similar to Merced clay loam.

Only one body, totaling 4.0 square miles, occurs in the southern part of the county near Hacienda Ranch where it is bordered on one side by Merced clay loam and on the other by the Tulare and Hacienda soils. It differs somewhat from the clay loam type in that it is influenced to some extent by the other soils around its outer border.

Merced silty clay loam, shallow phase (over Lethent soil material).—Normal Merced silty clay loam was not recognized in this county but is represented by a shallow phase formed by a rela-

tively shallow deposit of Merced silty clay loam material which has been superimposed over older material of the Lethent soils. As such it retains some of the characteristics of both soil series. The dark-gray or dark brownish-gray surface soil is 1 to 8 inches thick. The deeper surface soil is generally near the eastern edge of the soil area where it joins the other Merced soils. The texture is typically silty clay loam, but small areas of loam and fine sandy loam are included within the area mapped. A granular or lumpy structure prevails in the surface soil. The upper subsoil is a brown hard blocky layer of heavy clay loam texture. The lower subsoil is brown and somewhat mottled with rust brown, is heavy textured and structureless, and is encountered at an average depth of about 14 inches. The subsoil is more like the Lethent than the Merced soils in color and character of soil material. The soil is calcareous throughout and segregated gypsum occurs in the lower subsoil.

The relief is generally flat and the alkali content high; therefore, the vegetative cover of grasses is sparse. This type usually has less value for grazing purposes than Lethent silty clay loam. Small areas are occasionally farmed with the Merced soils, but where these two soils join, the Merced characteristics dominate and the alkali condition is less serious. Most of the 6.4 square miles mapped occurs in narrow strips not more than half a mile wide and extending from the northwest corner south to a point 3 miles west and 1½ miles north of Stratford.

Nacimiento clay.—The surface soil is a calcareous clay that is light brown and sticky when wet but dries to a firm or hard cloddy brownish-gray or dark brownish-gray mass. When worked, it breaks into a brittle or firm cloddy condition that is reduced to a granular mass with some difficulty. The surface soil grades into a normally olive-gray or light brownish-gray subsoil generally of a clay texture and moderately or slightly compact at a depth of 6 to 15 inches. Normally, white accumulations of lime occur in a myceliallike form, filling or lining the surfaces of small tubular pores. When dry, the subsoil has an irregular, poorly developed blocky structure, which shows some glazing or coatings of colloidal material on the surfaces of the units. At a depth of 20 to 40 inches the subsoil grades into calcareous gray, somewhat rust-brown and yellow mottled, softly consolidated shale bedrock that is partly disintegrated and decomposed.

This soil, totaling 1.7 square miles, occurs only on the hills bordering Stoker Canyon in the extreme southwestern part of the county. It has a hilly relief with a slope gradient of 10 to 40 percent.

Nacimiento clay is used largely for grazing, although at times some grain is grown under dry-farming conditions on the slopes. When the season is favorable 15 to 20 bushels of wheat may be harvested, but at other times the wheat is pastured or cut green for hay. The soil has a good moisture-holding capacity.

Panoche clay loam.—The soil is typical of the Panoche series and conforms closely to the series description. The light grayish-brown calcareous clay loam surface soil contains considerable silt. When disturbed the soil forms large firm clods or lumps that are reduced with some difficulty to a granular or powdery mass when worked during a fairly dry state. The surface soil grades into a grayish-

brown subsoil at a depth of 10 to 20 inches. This material generally has some indistinct veins of segregated lime lining the small tubular pores that generally are present throughout the soil profile. The subsoil is normally a clay loam or a silty clay loam and is similar in most respects to the surface soil. The material underlying the subsoil at a depth of 30 to 46 inches is generally light grayish-brown silty clay loam or loam.

This soil occurs mainly in the southwestern part of the area: In McLure Valley, in Avenal Gap and the adjacent part of the Kettleman Plain, and in the general vicinity of Murray. An area of 27.8 square miles is mapped.

Panoche clay loam is deep and permeable and potentially well suited to a wide range of crops, but it is without irrigation water except for two small areas, one near Murray and the other just north of the Kern-Kings County line in the Kettleman Plain. Both of these areas are watered from deep wells. The area near Murray is planted to olives that yield about 2 tons an acre. Grain produces 10 to 30 bushels and flax about 20 bushels. In the Kettleman Plain cotton yields about 1 bale. Of all the soils in the western part of the area this soil is best adapted to dry-farmed crops, and considerable areas in McLure Valley and the Kettleman Plain are used for dry-farmed grain. Yields are fair but entirely dependent upon the quantity and timeliness of rains during winter and early in spring. In McLure Valley the soil is free of alkali, but all other areas are slightly affected except for a few small areas in Avenal Gap that are moderately or strongly affected by accumulations of salts.

Panoche fine sandy loam.—The 9- to 15-inch surface soil is brownish-gray or light grayish-brown calcareous fine sandy loam that is soft and does not bake on the immediate surface and is easily worked to a fine-grained mass. The subsoil is a permeable light grayish-brown fine sandy loam that in places contains a few threads of segregated lime. In some places the subsoil texture may verge on a loamy fine sand and in other places may be almost a loam, depending upon stratification. The loose light grayish-brown underlying material occurs at a depth of 26 to 38 inches and consists of calcareous variable light-textured material that may contain layers of coarse sand or gravel derived from sandstone and shale rocks.

This soil occurs in numerous bodies bordering the hills in the southwestern part of the area. The largest body of the 46.0 square miles mapped occurs northwest of Milham City and includes a few small areas that have a slight subsoil compaction not typical of the Panoche soils.

Panoche fine sandy loam is soft and permeable to a depth of 6 feet or more, and, if irrigated, it is suited to a wide range of crops but, owing to a lack of available irrigation water, is largely in an uncultivated natural state. In the vicinity of Murray, a small area of this soil is used for dry-farmed grain in connection with Panoche clay loam, but the rainfall is too low in this locality for dry farming to be carried on extensively with any measure of success. The soil, however, does support a native cover of bromegrasses, foxtail, alfileria, and other annuals that flourish for a few months in spring and early summer and afford some grazing for sheep and beef cattle.

Most of this soil, except those bodies located in the McLure Valley, is affected by slight concentrations of alkali inherited from the saline

character of the parent rocks from which the soil material originated. The soil is well drained, and with suitable irrigation water the small quantity of salts, mainly sulfates, could be easily removed to lower depths by leaching.

Panoche fine sandy loam, beach phase.—The calcareous grayish-brown fine sandy loam surface soil is similar in most respects to the surface soil of Panoche fine sandy loam. The underlying material occurs at a depth of 10 to 50 inches and consists of light-gray calcareous loose loamy fine sand or fine sand that is similar to the underlying material of Tulare fine sand or Tulare fine sandy loam.

This phase (1.3 square miles) occurs along the edge of the Tulare Lake Basin just east of Kettleman City. It occupies a narrow strip along the old lake shore where Panoche fine sandy loam material has encroached, through movement by wind, upon some of the lighter textured soils of the Tulare series.

This soil is not cultivated; because moderate or strong alkali accumulations exist throughout most of its occurrence. Native vegetation consists for the most part of saltgrass, *Atriplex*, and other salt-loving plants that have a low value for grazing purposes.

Panoche loam.—Typically the surface soil is a light grayish-brown or brownish-gray calcareous loam that is 9 to 17 inches thick, but in some places the texture is heavier than typical, approaching a clay loam. The subsoil is a very permeable calcareous fine sandy loam or heavy loam of grayish-brown or light grayish-brown color and commonly contains small quantities of segregated lime. At a depth of 35 to 40 inches the subsoil grades into variable-textured loose stratified material.

This soil occurs in a number of small- and medium-sized bodies, totaling 16.2 square miles, on the plains and valley floor of the southwestern part of the county. A fair-sized area, however, occurs in the general vicinity of Avenal and north and northeast of Murray. A small body on the west side of McLure Valley is not typical, having some pieces of gravel and stones on the surface; this small area is differentiated from the typical soil by gravel symbols. In general Panoche loam conforms to the description of the Panoche series.

Although Panoche loam is potentially well suited for intensive agricultural practices, it is without water supply for irrigation, and only a small area of it near Avenal is cultivated to dry-farmed grain. Depending upon the season, the wheat produces 2 to 30 bushels an acre. The areas in the McLure Valley are free of alkali, but all others are slightly affected by salts inherited from parent soil material.

Panoche loamy fine sand.—The surface soil is light grayish-brown or light brownish-gray slightly calcareous loamy fine sand that is loose, open, and fine-grained. It extends to variable depths, depending upon stratification, but normally ranges from 6 to 15 inches thick. The underlying material extending to a depth of more than 6 feet consists of variably light-textured calcareous stratified recent sediments that frequently contain some coarse sand and gravel of sedimentary rock origin.

This soil occurs as small isolated bodies in the Kettleman Plain, on the alluvial slopes below the Kettleman Hills, and just south of Dudley Ridge. Usually these small bodies represent the most recent outwash of alluvial materials from the sandstone and shale hills and occur at

the lower end of steep-sided deep gullies, or barrancas. The soil is generally closely associated with other soils of the Panoche series, mainly the fine sandy loam or with the lighter textured soils of the Lost Hills series. The small bodies located just south of Dudley Ridge have a somewhat irregular microrelief resulting from wind drifting, but other areas have a smooth sloping relief characteristic of the soils of the Panoche series. An area of 7.6 square miles is mapped.

The soil has a very low water-holding capacity, and none of it is cultivated at the present time, although it supports some native grasses that are suitable for grazing. Most of it is slightly affected by alkali that is inherited from the saline sandstone and shale rocks from which the soil material originated. This soil generally supports a growth of *Atriplex* and other shrubby plants that often mark the occurrence of the soil where associated with the predominantly grass-covered Panoche fine sandy loam.

Pond loam.—The surface soil is shallow compact light-gray or light grayish-brown loam, and the subsoil is very dense and compact, but it becomes more permeable below a depth of 40 to 60 inches. The surface soil is usually very low in content of organic matter. The dense compact subsoil does not allow free penetration of roots and moisture. Within areas of Pond loam small barren flat shallow depressions, or playas, retain the surface drainage water that gathers in them during winter and spring rains. Very little of this percolates into the soil; most of it remains in the depressions until it is evaporated.

An area of 1.7 square miles occurs in two bodies about 4 miles north of Corcoran. The vegetative cover is sparse and is limited to alkali-tolerant grasses and weeds. The salt content is high, and black alkali is generally present. It is not recommended that reclamation be attempted because of the high alkali content and the dense impervious subsoil. It is used only for grazing for which it has little value.

Riverwash.—This miscellaneous land type consists of areas of sand or fine sand occupying stream channels that are subject to overflow by spring floods but may be dry the rest of the year. This material contains no appreciable quantity of organic matter, is loose, open, and leachy, and is unfit for cultivation. The material may support some weeds and a few willows marginal to stream channels; otherwise it is barren.

Riverwash is of little economic importance but in a few localities it is of some value in furnishing a limited quantity of browse grazing and watering places for livestock.

Rossi loam. This soil is representative of the Rossi series in color and in sequence and character of soil layers. The dark-gray calcareous loam surface soil puddles easily and is hard and cloddy when dry. White accumulations of salts on the surface are common during the summer months, but these salts are not evident during the wet winter when the soil is generally very sticky and slick. Little black alkali is present. The subsoil and underlying substratum are olive gray when moist but gray when dry. They are stratified and variable in texture and depth. Nodular accumulations of lime are common. Root penetration is not deep; only the more hardy saltgrass roots go into the lower subsoil and substratum.

An area of 18.0 square miles occurs in numerous bodies northwest, south, and west of Lemoore, northwest of Corcoran, and near the Malga Irrigation District reservoirs. It is generally flat but has many shallow winding drainage channels with poorly developed surface drainage and a ground-water table that fluctuates with the seasonal changes. Areas may be covered with floodwater during the rainy season.

Rossi loam is best adapted for grazing, having an average carrying capacity of about 50 to 70 head of cattle a section if the soil is flooded during spring. During 1936, 1937, and 1938, there was a tendency for dairy farmers to buy or rent small acreages, build homes, and attempt to farm this soil. The probable result of this recent trend can be reasonably predicted by observing the abandoned weather-beaten homes erected by ranchers who made similar attempts at an earlier date. Alfalfa yields now will average less than 1 ton a cutting an acre, and these yields will decline with continued irrigation, high water table, and further concentration of salts in the root zone. The high water table also limits the feeding zone for plant roots and results in the development of a shallow rooting system during spring and early in summer, and later when the water table is lowered the plants are unable to obtain soil moisture. This soil is best adapted to grazing in large tracts or farming to grain on an extensive and speculative scale.

Rough mountainous land.—The area of rough mountainous land is too steep and too broken, and the soils are too shallow to have any agricultural value other than grazing. The soils are quite stony, and large rock outcrops are common. These soils are developed in place on metamorphic or sedimentary rocks that have been much broken and shattered by earth movements. The soils are for the most part heavy textured, brown, and noncalcareous or only slightly calcareous in the surface soil with irregular calcareous subsoils. In general they probably conform mainly to the Altamont soils. They seem to receive more rainfall than other areas farther east and occasionally heavy rains of cloudburst character occur. They have a grass, shrub, and brush cover. Most of the 63.1 square miles mapped is in the southwestern part.

Temple loam.—This soil has a very dark-gray loose friable and granular surface soil, containing large quantities of organic matter and ash derived from the decay and occasional burning of a rank vegetative cover. In areas cultivated for some time this accumulation has become incorporated with the mineral soil and is less evident, although the loose granular condition remains. This surface layer is variable in thickness, but the upper subsoil lies at an average depth of 9 inches. The gray or dark-gray soft cloddy friable loam subsoil shows the influence of the organic layer above, but it is gradually replaced by the olive, greenish-gray, or brownish-gray lower subsoil. This layer may contain large hard lime carbonate nodules. The underlying substratum is a brownish-gray highly micaceous loose sand. The subsoil is calcareous, but the surface soil may or may not be calcareous.

An area of 3.9 square miles occurs in small areas in the northwestern part of the county and extends south along the slough bottom for a distance of 5 miles. The relief is irregular with large mounds rising

3 to 8 feet above old wide meandering sloughs that have not carried water for some time. The water table fluctuates but is near the surface during the rainy season, and, during periods of severe floods when levees along Fresno Slough break, the whole area is likely to be flooded. The smaller areas are usually farmed with associated soils to corn or alfalfa; otherwise they are used for pasture for which they are well suited. The larger areas are used for pasture or dry-farmed to small grain or corn. Because of its irregularity, fields that will some day be leveled and cultivated will be small and irregular in shape. A spotted alkali condition exists, but it is not severe. Floods offer the chief hazard to cultivation of this soil.

Traver fine sandy loam.—This type closely conforms in general characteristics to the Traver series as described. The light-gray surface soil is hard and compact when dry despite the fine sandy loam texture, and the subsoil is still more dense and compact. Generally the subsoil lies about 8 inches below the surface and the underlying loose substratum at about 16 inches. It always has a strong or moderate content of alkali that prevents the growth of any except the most tolerant vegetation, and this forms only in a thin cover. The content of organic matter is very low, and relatively few roots penetrate the soil.

This soil type is extensive (20.7 square miles) and occurs in numerous bodies of variable size in a circular strip 1 to 3 miles wide and extending from a point 4 miles south of Lemoore, east to Cross Creek, and then northeast to the Tulare-Kings County line. The largest bodies are east of Cross Creek and occur in the outer fringes of the Kaweah River fan, which enters the east side of Kings County from Tulare County. Other small isolated bodies are on the Kings River fan east of Hanford. The general relief is irregular and cut-up by stream channels, and in the larger areas the surface is interrupted by small mounds. Its general location on the outer fringes of these large river fans usually results in a high water table and impaired surface drainage. The underlying substratum, however, is quite permeable, and where the water table has been lowered enough to allow adequate internal drainage the soil can be reclaimed if the alkali content is not too great. The process of reclamation requires several years and an adequate supply of good water so that the salts can be leached downward and out of the root zone. The first crop generally grown in reclamation practice is sweetclover followed later by alfalfa. The application of barnyard manure aids in establishing a crop. Yields on these reclaimed soils are good but somewhat lower than yields on the Grangeville soils. It is recommended that reclamation attempts be limited to small areas that interfere with the cultivation of associated good soils. The larger areas on the fringes of the fans are too slowly permeable and contain too much alkali to permit their economical reclamation at the present time, if at all. This soil is not suitable for agriculture and is one of the poorest grazing soils in the area. The native vegetation is limited to saltgrass and alkali weeds and shrubs of low grazing value. Some grazing is obtained for a short time after spring rains (pl. 3, *B*), but the grasses dry quickly, leaving only the alkali-tolerant plants.

As mapped a few small areas are included that have a compact subsoil intermediate between that of Traver fine sandy loam and the very dense compact and deep subsoil of Pond loam. One of these areas occurs west of the Excelsior School; the others along the east county

line between a point 3 miles north and a point 13 miles north of Corcoran. These last small bodies generally represent the very tip-end extensions of Waukena fine sandy loam, which is mapped in the Visalia area, but because of their very small extent and less typically developed subsoils they were included with the Traver soils of Kings County.

Traver loam.—The surface soil of Traver loam is heavier textured than that of Traver fine sandy loam, and, although it has about the same light-gray color, it is more dense and less permeable to moisture and roots. The subsoil and substratum are similar to those of the fine sandy loam type. The soil is typically almost bare of vegetation, and the surface is interrupted by low mounds and drainageways.

Many small bodies totaling 1.0 square mile occur in the eastern part of the county and in the vicinity of Cross Creek. The largest body is about 6 miles northwest of Corcoran along Cross Creek. The soil normally has a high alkali content, and its reclamation is not economically feasible at this time. It has even less value than Traver fine sandy loam for grazing purposes.

Tulare clay.—This soil is representative of the Tulare series as described. The dark-gray heavy clay surface soil must be tilled under a narrow range of moisture conditions because of its heavy plastic nature; however, if plowed at the optimum moisture condition it is friable and granular and makes an excellent seedbed. Where the soil is allowed to dry undisturbed a coarse blocky or adobe structure develops, with cracks 1 or 2 inches across at the top and extending to a depth of 12 to 25 inches. In cultivated fields, where a good surface mulch is maintained, these cracks do not develop. The subsoil has an excellent coarse granular or irregular fine blocky structure and a slightly lighter color than the surface soil. It generally occurs at a depth of 15 to 45 inches. Below the subsoil the gray or dull-gray substratum is usually a soft or semiplastic laminated layer containing rust-brown mottlings and segregated gypsum. Some variability in this soil due to stratification is characteristic. The soil has a good moisture-holding capacity and is easily penetrated by plant roots, although considerable damage is likely to result to roots where cracking occurs in a dry condition. The alkali content is considerably greater in the substratum than in the surface soil, and in fields that require several irrigations during the summer care must be exercised that the soil does not become unnecessarily dry. After the soil has been saturated and allowed to dry, the salts, which were dissolved, are returned and deposited in the root zone, where their gradual accumulation over a period of time will result in a serious problem. The occasional flooding, however, which this soil receives, together with the usual practices of prolonged irrigations before planting crops, very greatly aids in keeping the salts below the plant-root zone. Strips of soil 1 to 3 rods wide containing strong concentrations of alkali parallel drainage and irrigation canals that contain water a greater part of the year.

It is the most extensive soil type mapped, having a total area of 236.1 square miles. A large body and several smaller areas occur in the basin of Tulare Lake southwest of Corcoran. It is characteristically a lake-bottom soil. Most of T. 22 S., R. 20 E., was submerged by floodwaters during the period of this survey and could not be mapped. The soils in this part of the basin are, however,

uniform, and this unmapped part is probably covered by Tulare clay. Where major streams have emptied into this basin the substratum is likely to be more stratified and sandy than typical, and a droughty condition may result where these sand pockets are too near the surface.

The entire area can be cultivated; however, the percentage actually cultivated varies from year to year and depends either upon the area covered by the previous season's floodwaters or the quantity of water available for irrigation from ditches and canals. During periods of dry years it is necessary to irrigate from wells, but much of the area depends entirely upon ditch water for the preirrigation in fall and for the winter rains to mature the crop. Wells are expensive to drill and maintain for they go to depths of 1,500 to 2,000 feet, and it is the general rule that one well should irrigate one section of land.

Wheat and barley are the two grains grown. Barley is somewhat more drought-resistant, and for that reason it is grown largely on the west side of the lake. The Mariout variety is very drought-resistant, but about 90 percent of the barley acreage is of the Atlas variety. Generally acre yields range between 40 and 75 bushels. Yields of wheat range between 35 and 42 bushels an acre. Baart, Sonora, and Federation represent the commonly grown varieties of wheat. Pure seed of these varieties is produced and sold throughout the State. All seed planted is treated for rust and smut before planting. Resistant varieties are, however, being developed and should soon be available. Yields of both grains fluctuate from year to year and are almost entirely dependent upon the quantity of available irrigation water. The general cultural procedure is to burn the straw and stubble as soon as harvesting by combine is completed in June or July. This is followed by disking or plowing or by irrigation and later plowing, depending on local conditions. Planting is completed by December, and during March the second irrigation is applied, provided the season's rainfall has been less than 5 or 7 inches. The stubble is usually burned to prevent a disturbance of the soil-nitrogen balance and the subsequent curtailment of the next season's crop.

Cotton acreage is increasing yearly but there are areas where this crop will not grow because of alkali. Cotton must be watered during the summer, and this has a tendency to draw the salty water of the subsoil to the surface where the salt in solution is accumulated on or near the surface by evaporation. Cotton yields 1 to 1¾ bales an acre. Its culture and water requirements are greater than for grain. The cultivation of sugar beets has been increasing within the last few years, but it is still largely in the experimental stage. Yields on the small acreage planted in 1936 was 12.5 tons an acre, though test plots produced 18 to 20 tons the same year. The flat topography of the lake basin makes the removal of surplus irrigation water by surface drainage a problem, and consequently beets have been damaged some by scalding and heart decay.

Grain is the important crop of this soil, although the acreage of cotton will continue to be large and in time sugar beets may be as important as cotton. The alkali in the substratum is an ever-present menace. The flooding of this soil in wet years and lack of sufficient water for irrigation during dry seasons necessitates large money ex-

penditures for protective levees and deep wells. For this reason the unit of farming on this lake-bottom soil will probably continue to be very large, comprising several or many sections with holdings by large companies or organizations rather than by individuals of limited financial resources.

Tulare clay loam.—This soil follows closely the description given for the Tulare series, and in its general features, such as culture, drainage, and field yields it is practically identical to Tulare clay. The dark-gray clay loam surface soil breaks into an excellent soft granular condition when plowed at favorable moisture content. It has a good water-holding capacity and is high in content of organic matter. The subsoil is less uniform with respect to depth and color than the Tulare clay subsoil, but the texture is uniformly heavy. The soil is calcareous and contains slight or moderate quantities of salts in the subsoil and substratum. These salts have a tendency to rise to the root zone if the soil is improperly irrigated. This soil, as is true of Tulare clay, rarely contains black alkali. A rank growth of tules once flourished on this soil, and fires occasionally burned off the accumulated dry plants. These fires caused the soil material in places to become baked to a reddish-brown hard bricklike condition, and under cultivation this material breaks into small irregular fragments. This condition occurs along the Tule River south of Corcoran, and spots extend south around the former lake margin to the general vicinity of the Liberty Farms. This material is an aid to cultivation by causing the soil to develop a more friable tilth, and its quantity is usually not great enough to impair the water-holding capacity.

Tulare clay loam covers an area of 59.0 square miles around the entire lake at about the 190- to 200-foot level. Several areas are south of the sand ridge near the Hacienda Ranch, a small nontypical area joins the Visalia area 3 miles northeast of Corcoran, and elongated strips are mapped south of Dudley Ridge that are hardly typical of Tulare clay loam but tend to approach the Hacienda soils.

This soil lies so nearly flat that surface drainage depends on canals and ditches, consequently any crop such as sugar beets which is likely to rot or scald from excess surface water will require special attention and care. Over a period of dry years the ground-water level is below the danger zone, but during wet years this soil, like Tulare clay, is subject to high water table or flooding. Wheat is the most important crop and yields from 35 to 42 bushels an acre. Cotton is proportionately more important on this soil than on Tulare clay, but the yields are about the same, with an average of about 1¼ bales an acre. Some alfalfa in the vicinity of the Tule River yields about 1 ton for each cutting and has an average life of 6 years, whereas alfalfa on the Grangeville soils must be reseeded after 4 years. The soil is best adapted to grain, for it requires less irrigation and is less likely to be damaged by the alkali content. The level fields are also well adapted to the use of heavy farming machinery required in large-scale farming.

Tulare fine sand.—The surface soil is a light-gray loose calcareous fine sand containing very little organic matter and has a low water-holding capacity. The olive-gray heavy-textured stratified subsoil layer usually lies below 20 inches. Shell fragments are scattered throughout the soil, and the subsoil commonly contains large quantities of black alkali. The surface soil contains very little alkali.

Tulare fine sand covers an area of 13.9 square miles. The larger areas occur along the old beach line of Tulare Lake from Kettleman City, south around Dudley Ridge, and east past the Hacienda Ranch to the east county line.

This soil has an irregular wind-modified microrelief. Small elongated or circular mounds rising 10 to 20 inches above the general level are common throughout the area. The soil has a very low moisture-holding capacity and supports only a scattered cover of saltgrass and other alkali-tolerant plants. It is used only for grazing and is similar to Tulare fine sandy loam and the soils of the Hacienda series in that it is one of the poorest soils in this area for grazing purposes.

Tulare fine sand, beach phase.—This phase is a light-gray loose wind-blown fine sand that rises from 5 to 15 feet above the general surrounding level, and although it rests on heavier textured layers they may be buried quite deeply. It consists of an elongated narrow ridge of fine sand that extends from Dudley Ridge east past the Hacienda Ranch to the Kings-Tulare County line. The northward slope is gradual and rather uniform but the south side is abrupt. The winds which modified this ridge came down the valley from the northwest. The soil is sparsely covered by deep-rooted saltgrass, and in barren spots sand blows badly. Several large sand dunes occur at Dudley Ridge, and the sand blows badly just north and west of the Hacienda Ranch. An area of 6.5 square miles of this soil is mapped. It has very little grazing value.

Tulare fine sandy loam.—The surface soil is a loose structureless gray or light-gray calcareous fine sandy loam containing many shell fragments, but it is practically free of alkali. Its depth depends on local conditions and ranges from 4 to as much as 30 inches, but 10 inches is an average. The content of organic matter is very low, and the soil has a low moisture-holding capacity. The subsoil consists of gray or olive-gray variable-textured stratified layers containing strong concentrations of black alkali, and roots do not penetrate them deeply.

Tulare fine sandy loam occurs in large and small areas around the lake basin margin. It represents the old beach line and largely borders Tulare loam or Tulare clay loam on the lower side. An area of 60.1 square miles is mapped with the largest area occurring east and south of Dudley Ridge. As mapped this soil type includes some small areas of very fine sandy loam.

Most of this soil is used for grazing. Small areas, however, are occasionally dry-farmed to grain with a yield of 8 to 12 bushels an acre. Better yields are obtained when the lake basin contains enough water either to raise the ground-water level in these soils or to permit their being watered from canals. Under continued cultivation, which is by no means the rule, the alkali content of the subsoil would soon rise and make farming impossible. In areas where the surface soil is a thin layer resting on heavy-textured material, as in the vicinity of Dudley Ridge, deep plowing may alter the surface texture by mixing the clay with the fine sandy loam surface soil.

The native cover consists largely of saltgrass with scattered alkali weeds and shrubs. Grazing represents the most consistent use that can be made of this soil even though its value for this purpose is very low.

This soil becomes somewhat finer in texture where it merges with and joins with Tulare very fine sandy loam of the adjoining Pixley area.

Tulare loam.—The dark-gray loam or light-textured loam surface soil has a well-developed granular or soft cloddy structure. It contains a moderate quantity of organic matter, has a good water-holding capacity, and can be tilled under a wider range of moisture conditions than the heavier textured Tulare soils. The subsoil and substratum are much more stratified and irregular in depth and texture than in the Tulare clay loam or clay. The soil is calcareous, and some black alkali is present in the subsoil.

In general Tulare loam occurs as a strip around the lake basin between areas of the Tulare clay loam and fine sandy loam. An area of 38.0 square miles is mapped. The largest and most typical body is 11 miles south of Corcoran. The larger areas include narrow strips of fine sand where the fluctuating waters of the old beach once stood, but these have been leveled by cultivation and are no longer prominent. Several other areas are located south of the sand ridge in the vicinity of the Hacienda Ranch.

The relief is flat giving poor surface drainage, but this soil occupies a slightly elevated position where ditch water is less plentiful and use depends to a greater extent on the seasonal rainfall. Wheat is the main crop yielding from 30 to 40 bushels an acre, but the yield depends on the quantity of available moisture the crop receives. Because of the quantity of alkali in the subsoil, Tulare loam is somewhat more subject to the rise of alkali than the Tulare soils of heavier texture.

DRAINAGE AND IRRIGATION

The reclamation of swamp and overflow lands and the construction of irrigation systems were of primary importance in bringing much of the arable lands of Kings County into intensive agricultural production. Prior to the construction of levees for flood control, floodwaters of the Kings River spread over its alluvial fan by means of a great number of small stream channels or sloughways. Many of these channels, as did the main channel, led into Tulare Lake, but some meandered northwestward to form Fresno Slough, which joins the San Joaquin River in Fresno County. It was therefore necessary to confine the Kings River between levees and control its flow southward into Tulare Lake or northward by means of Fresno Slough into the San Joaquin River before the overflow lands of the delta could be safely cultivated or irrigation systems constructed.

By an act of Congress in 1852 the swamp and overflow lands belonging to the Federal Government were granted to the States; subsequently in 1857, the California Legislature passed an act authorizing reclamation of swamp and overflow land lying between the Kings River and Buena Vista Lake in Kern County, and the construction of a canal connecting the San Joaquin River with Tulare Lake and Tulare Lake with Buena Vista and Kern Lakes. Because of financial difficulties the task was abandoned in a few years. The State then opened up the overflow and swamp lands for sale to the general public at $2.50 an acre. Drainage of Tulare Lake by means of a

canal was never attained,[13] but a series of dry years, which lowered the level of the lake considerably and ultimately dried up the lake completely for a time, favored the erection of levees and the establishment of reclamation districts (*20, 21*).

The first reclamation district along the Kings River was organized under State law in 1890 (*8*), but most of the districts were formed between 1906 and 1909. In 1930, 8 reclamation districts were active in controlling water flow along most of the Kings County part of the Kings River. A large number of the 25 reclamation districts listed in 1930 in Tulare Lake basin were organized between 1899 and 1905, but the levees constructed in that period were not adequate to confine the water in the lake in 1906, and in most instances the water surface conformed to the natural contours of the lake basin. After 1908, dredges were used to construct most of the large levees that now crisscross the basin, and since that time the water of the lake has been confined to a part of the original bed by large levees. The flow of the Kings and Tule Rivers was controlled from where these streams originally emptied into the lake and was conducted to a leveed area of 18 square miles (north half T. 22 S., R. 20 E.) in the center of the lake basin. The high water of 1906 flooded a number of reclamation districts, but after that the water in the lake was controlled by levees in a definite impounded area until 1938.

In 1927 the Tulare Lake Water Storage District was formed for the purpose of storing water for irrigation for the benefit of all reclamation districts. The 36 square miles of T. 22 S., R. 20 E., and about the north 12 square miles of T. 23 S., R. 20 E., were assigned for a definite storage and overflow-storage area, and the levees of this reservoir were high enough and strong enough to impound water up to 192 feet above sea level. The period between 1916 and 1937 was for the most part dry, and most efforts were diverted from flood control to obtaining water for irrigation, particularly during the dry period between 1924 and 1937 when a number of deep wells were drilled in the lake bottom. In the spring of 1937, the reclamation districts were again faced with a flood problem. River channels leading into the lake bottom had to be cleared of tules and refuse, and levees restrengthened and built higher. The close of the 1937 season found the storage area nearly full, and the high runoff late in the spring of 1938 filled the reservoir and then broke through levees to flood many of the reclamation districts despite labor and equipment to keep the water impounded.

Kings River is the chief source of ditch irrigation water in Kings County. At Piedra, a point on the river above any diversion of water for agricultural use, records of stream flow kept since 1896 by the water master of the Kings River Water Association show the normal annual flow at this point to be 1,650,900 acre-feet, the maximum for any year (1906) 3,917,800 acre-feet, and minimum (1924) 399,500 acre-feet. There is a considerable normal seasonal fluctuation of the river, as shown by figure 4, *A*. The entire flow of the river, however, does not reach Kings County; between 45 and 65 percent of the water, depending upon the flow at Piedra, is diverted for irrigation purposes in Fresno and Tulare Counties.

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[13] WEIS, M. B. TULARE LAKE HISTORY GAINS INTEREST IN RELATION TO PRESENT FLOODS. A series of articles appearing in the Hanford [Calif.] Morning Journal, May and June 1938.

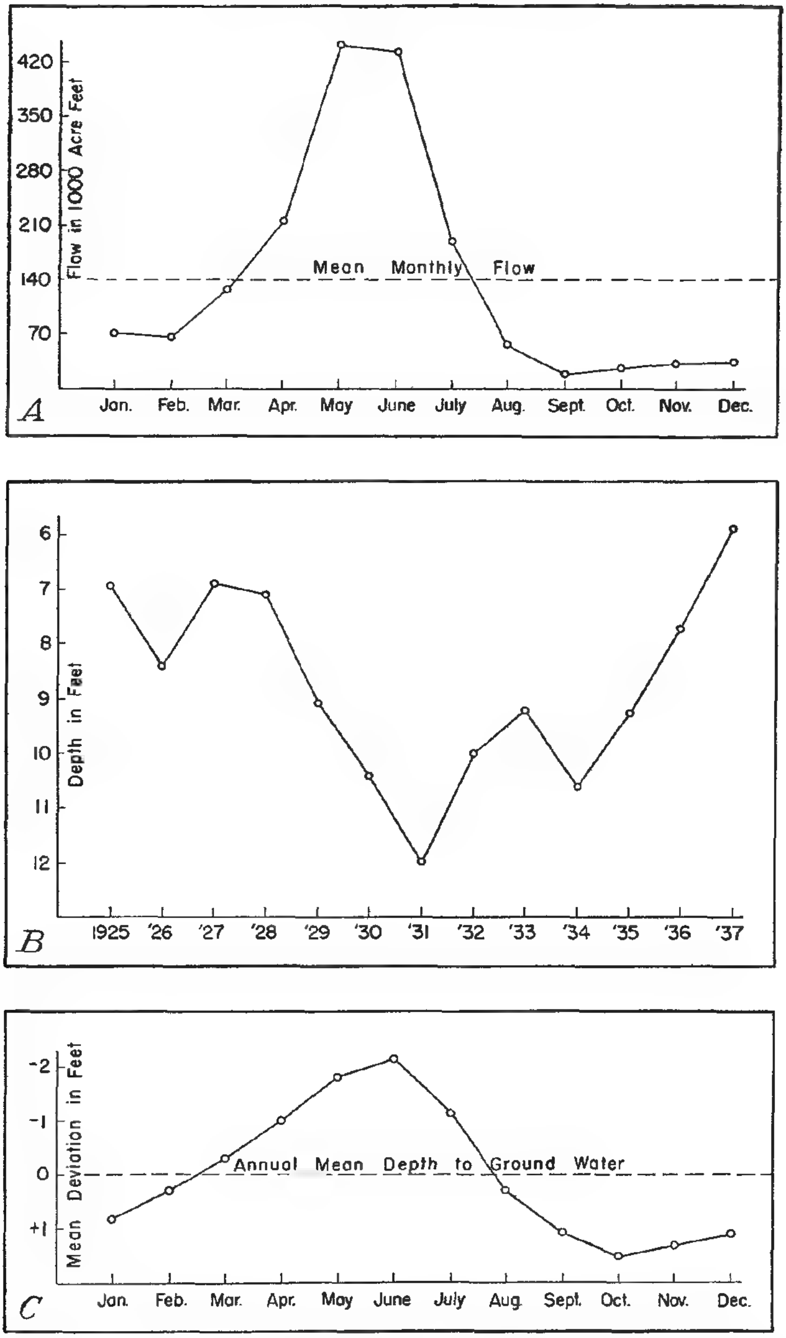


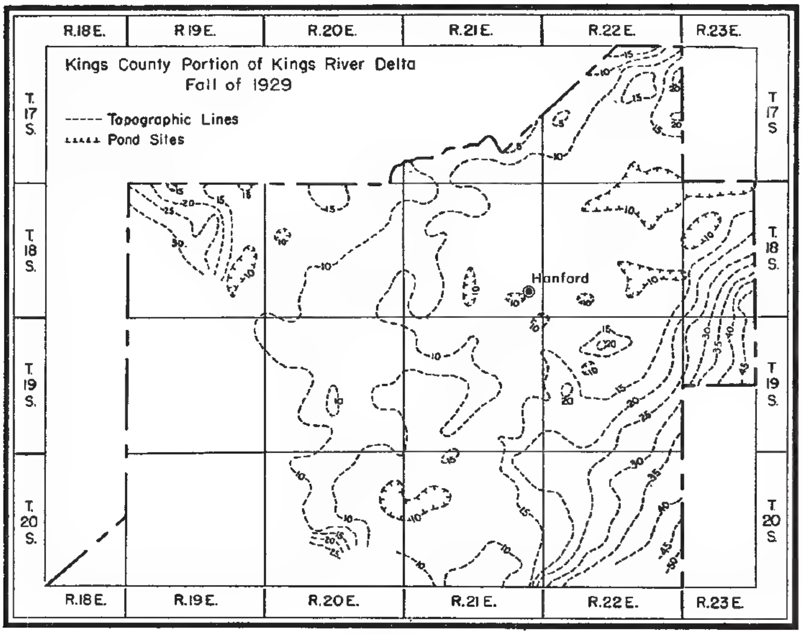
FIGURE 4.—*A*, Average seasonal fluctuation of Kings River at Piedra; *B*, average depth to ground water in Hanford, Lemoore, and Stratford districts for the years 1925–37; and *C*, average seasonal fluctuation of ground water in Hanford, Lemoore, and Stratford districts.

The first extensive irrigation in Kings County was accomplished by means of the Lower Kings River Ditch (*1*), later called the Lemoore Canal. which was completed in 1872. Shortly after the Peoples' Ditch was begun, and in 1873 the Last Chance Water Ditch Company was organized and its system completed. The early irrigation organizations were mutual companies in which each farmer acquired stock on the basis of one share to each section of land. The money was used for building the systems, and as the years went on assessments were levied to care for running expenses. In later years the Lakeland Canal, Riverside Ditch, Empire Canal, Blakely Canal, Crescent Canal, and other canal districts were organized and their systems completed. The Laguna Irrigation District, on the lower delta of Kings River in the northwestern part of Kings County and overlapping into Fresno County was formed in 1920 and comprises about half the area (34,858 acres) in the old Laguna de Tache Rancho, a land grant deeded to Manuel Castro in 1846 by the Mexican Government. These lands hold the oldest water rights on Kings River. The district when formed took over the canal system of the Fresno Canal Company. The Lucerne Irrigation District, an area of 33,407 acres, is covered by the Last Chance Water Ditch and its laterals. It is a short distance west of Hanford and was organized in 1925 primarily to deal with other Kings River water users in connection with the proposed storage at Pine Flat. The Corcoran District has a gross area of 51,606 acres, and the Lakeland District 23,282 acres.

Water from the Kings River is diverted into the Lakeland Canal only when the flow at Piedra exceeds 8,000 cubic feet a second; other sources of gravity water for these districts are Cross Creek, Mill Creek, Deer Creek, Deep Creek, and Elk Bayou. The water of all these minor streams reaches Kings County intermittently, and only in years of very high water does a flow pass the districts and enter Tulare Lake Basin. The Kern River, flowing northward through Buena Vista Slough and Goose Lake Canal, reaches Kings County and the basin only in years of high flood stage, and at such times the water is used for flooding land later to be planted to grain.

Surface irrigation and subirrigation are both practiced on the Kings River fan. Irrigation canals follow the low ridges of higher ground generally occupied by the very permeable Grangeville loamy fine sand. Few of the canals are lined, and consequently late in spring and in summer when the canals and river are full seepage raises the ground-water level to within a few feet of the surface, resulting in an accumulation of salts near the surface and in the plant-root zone. The salts accumulate slowly and the increasing quantities may be noticed by decades rather than by years. Because these salts move laterally as well as vertically, the areas affected first lie farther out on the lower part of the fan away from the river, the source of the ground-water supply. Figure 4, *B* shows the fluctuation of ground-water level between the years 1925 and 1937, and figure 4, *C* shows the normal seasonal fluctuations. These data were obtained from a number of well records made available through the office of the county farm adviser. Although surface irrigation is generally practiced on field crops, many orchards and vineyards have rarely been surface-irrigated. In the summer of 1937 a number of apricot and peach trees were killed, probably because of too high a ground-water level; vineyards were not noticeably affected. The depth (*9*) of ground-water table and the

A



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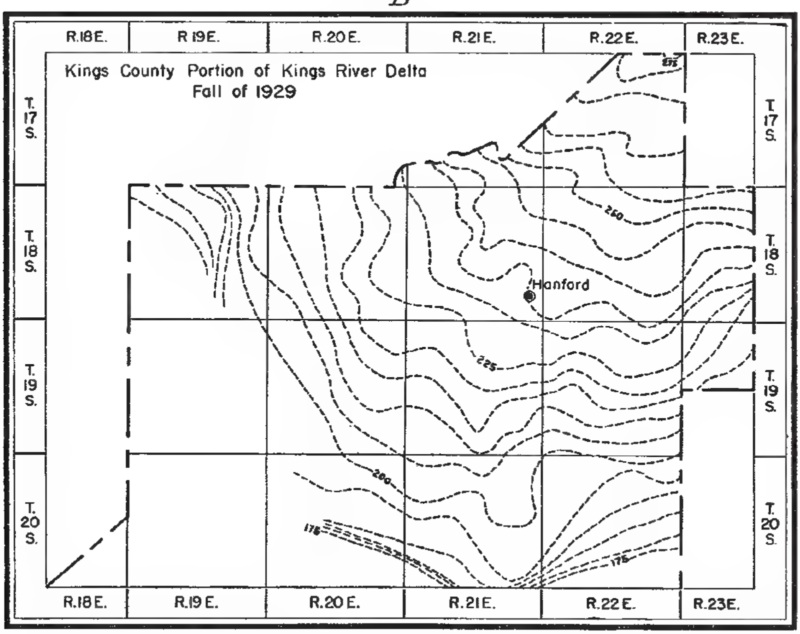

FIGURE 5.—*A*, Lines of equal depth to ground-water table; *B*, lines of equal elevation of ground-water table.

elevation of the surface of ground water above sea level for the Kings River delta in 1929 are shown in figure 5.

Gravity water for irrigation, particularly late in summer and early in fall when the river flow drops, is supplemented by water pumped from wells. At one time a good deal of the valley part of Kings County was in the zone of artesian flow, which follows along the general axis of the valley, but in the last 10 or 15 years the artesian wells gradually ceased to flow, until today few if any are active. At the present time electrically driven pumps of the centrifugal type for shallow wells and turbine types for deep wells are in general use in the irrigated parts of the area. The wells in Tulare Lake basin range in depth from 1,500 to 2,000 feet in order to tap water-bearing strata that are sufficiently free of salts to permit water to be used for irrigation. The lands west of the axis of the valley have no canal water available and therefore any crops that are grown, except occasionally some grain, depend upon well water for irrigation. Most of the wells of the west side are too salty and are insufficient in volume for irrigation, although they are used for watering livestock. Two small areas on the west side of the county, however, have water of suitable quality and volume for limited irrigation: The most important area is around Murray; the other area is close to the Kings-Kern County line in the Kettleman Plain. Practically no ground water is available for irrigation in McLure Valley. Suitable water in sufficient quantities to make irrigation practical is necessary for full agricultural development of the western part of the county.

SALTS AND ALKALI

The term "alkali," as used in this report, refers to all the soluble mineral salts that as a result of poor drainage and surface evaporation accumulate in the soil in sufficient concentration to injure plant growth. The accepted chemical usage divides the salts commonly accumulated in soils in the arid region into two groups. Saline soils (white alkali) are soils that contain, among others, chlorides and sulfates of sodium, magnesium, and calcium. Familiar and well-known examples of these are sodium chloride (table salt) and sodium sulfate (Glauber's salt). Black alkali soils (*19*) are those that contain sodium carbonate. Although both conditions exist in Kings County, the accepted local usage makes no distinction and designates both as alkali soils. The local usage will be accepted and used in this discussion.

White alkali salts are so named because of the white crust that frequently forms on the surface of the soil. They are neutral in reaction and considerably less harmful than the black alkali salts, which are recognized by dark-brown or black stains that form on the surface. Large quantities of white alkali will cause the surface soil to be puffy and loose. Frequently crystals of salt or firm crusts will develop within or over this puffy layer during the dry part of the year. Plants are tolerant of almost twice the concentration of white alkali as they are of black alkali.

If present in sufficient quantities to be harmful, black alkali is caustic or corrosive to organic substances and decaying organic matter (*5*). The residue from this chemical action is the easily recognizable thin black crust or film. A deflocculated or puddled condition of the soil also results where this salt is predominant. The pore

spaces are sealed over or clogged by the fine clay particles dispersed by this salt so that downward percolation of water is greatly retarded. This may give rise to the shallow ponds, or flat, slick, or barren playalike spots in which turbid surface drainage water stands until evaporated by the summer heat.

The salts in the soil result from the decomposition or breaking down of the minerals present in the parent soil material. In humid regions these soluble salts are removed from the soil in solution by percolating waters. In arid and semiarid regions, however, rainfall and percolating waters are insufficient to remove completely the salts formed in the soil. Because they are soluble and move freely in water they tend to accumulate along the lower outer fringes of river deltas and fans and in flat depressional areas and basins through evaporation of seepage and drainage waters, leaving their salty load in or on the surface year after year.

Five conditions or grades of alkali accumulation are recognized in Kings County, separated from each other on the map by dashes or broken red lines. The symbol representing each grade of salt concentration is shown in red and represents the range in salt concentration as given below.

Alkali concentration:	*Percent*
F (free)	0 to 0.2
W (weak)	0.2 to 0.5
M (moderate)	0.5 to 1.0
A (strong)	1.0+
S (spotted)	0 to 1.0+

The separations are made in the field by noting the quantity, kind, and thriftiness of the vegetation, the structure and consistence of the soil, the soil color, and the presence or absence of salt crusts. To check on the field observations and to maintain a uniform standard of mapping, alkali samples are taken at selected sites in the field to a depth of 60 inches. The percentage of total salts is determined in the air-dry soil by means of the Wheatstone electrolytic bridge. Presence of black alkali is determined by a simple color reaction with phenolphthalein.

The alkali symbol F indicates that the soil is free of harmful quantities of salts.

The symbol W indicates that weak or slight concentrations of salts are present, and that although the soils may be farmed and give moderate returns they are potentially dangerous if improperly handled or watered. Large areas of the Panoche, Lost Hills, and Kettleman soils, all in the western part of the county, are so mapped. These soils, however, are rarely farmed, owing to lack of irrigation water.

The condition mapped as M normally contains too much salt to permit profitable agriculture without some degree of reclamation. A few exceptions to this will be noted later. Normally these soils support a fair growth of grasses and other vegetation suitable for grazing, for which purpose they are largely used.

Areas mapped as A generally have a sparse or scattered vegetative cover consisting largely of such alkali-tolerant plants as saltgrass, pickleweed, iodine bush, and some *Atriplex*. Such soils have a very low value, as they afford only the poorest of grazing. They usually occupy shallow basinlike or flat areas with a playalike microrelief and puff spots with salt crusts on the slightly elevated areas. Permanent

reclamation is here extremely difficult and doubtful. In areas of symbol A the concentration of salts becomes somewhat less pronounced where these areas join with those mapped M in the adjoining Pixley area.

The symbol S indicates a spotted alkali condition in the field. Considerable portions of the areas so mapped contain no salts or only slight concentrations, but within such areas are small spots where the growth of plants is considerably retarded or even entirely prevented. These salt-affected spots are too small to permit individual differentiation on the map. Such areas cannot be considered as free of alkali but to map them as W would be incorrect. Though their number varies somewhat from place to place, a quantitative separation is impracticable. This condition is limited to the northeast part of the county, or that part occupied by the Kings River fan.

The reclamation of alkali soils presents many and varied problems (*17*). The relative proportions of replaceable calcium and sodium in the soil complex plays an important part in determining the feasibility of alkali reclamation. Such factors as localization of the salts in some layer of the soil, texture of the surface soil and subsoil, presence or absence of a claypan or hardpan, surface drainage, depth to water table, and chemical composition of salts and of irrigation water are all very important points to be considered.

White alkali can frequently be washed from the soil, provided the surface drainage and subdrainage are good and an adequate supply of good, fresh or only slightly salty, water is available. If the water table is low and the subsoil and substratum are open and pervious, the salts can frequently be leached downward by flooding. Where the subsoil is a claypan or is impervious, the salts can sometimes be partly removed by holding water on the affected areas and then draining it off to lower levels with the salts in solution, but this method is never very effective. When the soil contains black alkali, reclamation by leaching is much more difficult, as this salt causes dispersion of the soil colloids accompanied by a breaking down of the granular structure, sealing of the soil pores, and a condition relatively impervious to percolating waters. In soils containing large quantities of calcium less puddling occurs, as calcium is not so largely replaced by sodium in the absorption complex. The use of irrigation waters containing in solution large quantities of lime or gypsum may also have a beneficial effect. Areas having heavy-textured surface soils and dense compact subsoils, however, are very difficult to reclaim. The liberal application of gypsum or of sulfur to soils containing sodium carbonate is an aid to their reclamation. The quantity to be added will depend upon the content of lime and sodium carbonate in the soil and its texture. Light-textured soils require less treatment than those of heavier texture. The cost of such treatment, however, makes its wide application impractical at present.

With respect to treatment and use of alkali land, Kelley (*16*) states that the first economic crop to be planted should be alfalfa or some other thickly growing crop that requires the flooding system of irrigation. By this means the chemical transformations, initiated in the soil by the growth of alkali-resistant plants, will be completed. The essential chemical transformations that must be produced in soils that contain black alkali are the neutralization or precipitation of soluble carbonate and the replacement of absorbed sodium (black

alkali) by calcium. These transformations can be effected either by applying a soluble calcium salt, as gypsum, or by increasing the solubility of the calcium carbonate of the soil. The latter can be accomplished by applying sulfur or other acid-producing substances, or by growing Bermuda grass, white sweetclover, or other alkali-resistant plants. The carbon dioxide given off by the roots of these plants produces the needed chemical reactions, chiefly through its effect on the calcium carbonate of the soil. Results from following the above procedure are obtained only after judicious treatment for several years and should not be expected to be apparent at once.

An important point to remember in the treatment of alkali soils is the location of the greatest salt concentration in the soil profile. If the surface soils contain but slight quantities, whereas the subsoils and substrata layers contain potentially dangerous concentrations of salts, it is best to maintain a downward movement of moisture by frequent irrigation in order to prevent the rise of the salts by surface evaporation. Shallow-rooted crops, as grain and cotton, can be grown in such soils if the salts are kept down. The Tulare, Merced, and, to some extent, the Chino soils present such conditions. The consistently large yields of grains from the Tulare soils is possible only because the occasional floods and heavy preirrigations carry the salts lower in the soil. The grain is planted and makes most of its growth during the winter rains, the period of least evaporation. It is harvested about May 15 before the hot summer weather causes excessive evaporation. Cotton, however, requires several irrigations through the summer period of maximum evaporation. The alkali rises rapidly and results in a spotted, irregular, uneven stand of cotton.

The most harmful concentration of salts is on the immediate surface. The Foster and Grangeville soils deserve special attention in this respect. In the region south and west of Hanford to Lemoore these soils frequently contain strong concentrations of alkali on the surface and at the same time successfully grow peaches, apricots, and Muscat of Alexandria grapes. Owing to the high water table in this region, these crops are not irrigated. Most of the salts in the underlying materials are brought to the immediate surface and concentrated there by evaporation during the dry season. This leaves the soil below the 4- to 8-inch surface layer practically free of salts. Here the generally accepted practice is to plant the young trees and vines in imported alkali-free soil. In this medium the roots of the young plants develop and penetrate below the surface soil. Vineyards 60 years old with vigorous strong vines, as well as fruit trees, have been observed growing in fields having moderate to strong concentrations of alkali in the surface soil during the dry season. The high water table makes it impossible to leach the salts completely below the root zone. Alfalfa is planted in fall and spring, when the surface concentration of salts is somewhat lowered by penetrating rain water and the roots are generally below the danger zone when excessive evaporation occurs.

The Pond, Fresno, Lewis, Hacienda, Lethent, and some of the Tulare soils have moderate or strong alkali accumulations. Their heavy textures and compact and often impervious subsoils, together with the fact that they may contain large quantities of black alkali, make the possibility of their reclamation very doubtful. During abnormally wet seasons some grain is grown around the borders of Tulare Lake on areas that contain strong concentrations of alkali. This is

possible only because part of the salts has been washed down or out and the soil solution diluted.

It appears probable that the alkali conditions and problems of Kings County will become more acute, because of the present method of subirrigation and the consequent resulting high water table, although the effects are cumulative over a long period and are not startlingly apparent in one or two seasons (*11*, *12*, *14*, *15*).

SOIL RATINGS

In table 5 the soils of Kings County are rated by means of the Storie soil index (*26*), on a percentage basis, in terms of their potential suitability for the production of crops. In this system soil characteristics, as texture, structure, consistence, and other properties of the surface and lower layers, are considered, as well as drainage, relative freedom from salts, and relief, but not rainfall, available irrigation water, local climatic conditions, or other external features of like nature. The most favorable soil conditions are rated 100 percent. This index rating permits a comparison of the soils in this county with other soils of California, irrespective of location.

In this rating the soils are placed in six grades. Grade 1 soils (rated at 80 to 100 percent) are of excellent quality and suitable for a wide range of crops. Grade 2 soils (60 to 79 percent) are of good quality and suitable for most crops. Grade 3 soils (40 to 59 percent) are somewhat limited in their use by extremes of texture, by drainage, by heavy-textured subsoils, or by other soil factors, though some of those soils may have special adaptation for certain crops. Grade 4 soils (20 to 39 percent) are suitable for a few crops except grasses and shallow-rooted crops, or possibly alkali-tolerant plants where alkali is the limiting factor. Some soils in grade 4 may be raised to grade 3 by means of alkali reclamation, leveling, blasting hardpan, or other practices, and some individual areas would be rated higher. Grade 5 soils (10 to 19 percent) generally are of very poor quality for any cultivated crop. Grade 6 soils (index rating of less than 10 percent) are nonarable or nonagricultural.

TABLE 5.—*Ratings of soils in Kings County, Calif.*

Soil type	Alkali concentration [1]	Rating	Grade
Chino clay	W	29	4
	A	3	6
Chino clay loam	S	36	4
	W	32	4
	M	16	5
	A	4	6
Chino fine sandy loam	S	68	2
	M	38	4
	A	11	5
Chino loam	F	68	2
	S	61	2
	W	54	3
	M	27	4
	A	7	6
Commatti clay loam	F	79	2
Shallow phase	F	58	3
Dinuba sandy loam	F	76	2
	S	72	2
	M	38	4
	A	11	5
Foster clay	W	31	4

TABLE 5.—*Ratings of soils in Kings County, Calif.*—Continued

Soil type	Alkali concentration [1]	Rating	Grade
Foster clay loam	F	47	3
	S	43	3
	W	40	3
	M	24	4
	A	7	6
Foster fine sandy loam	F	76	2
	S	68	2
	W	65	2
	M	34	4
	A	11	5
Foster loam	F	71	2
	S	64	2
	W	60	2
	M	32	4
	A	8	6
Foster sandy loam	F	68	2
	S	62	2
	W	58	3
	M	33	4
	A	10	5
Fresno fine sandy loam	M	10	5
	A	3	6
Fresno loam	A	3	6
Grangeville fine sandy loam	F	86	1
	S	81	1
	W	77	2
	M	43	3
	A	13	5
Hummocky phase	S	75	2
	M	41	3
	A	9	6
Grangeville loamy fine sand	F	81	1
	S	77	2
	W	73	2
	M	45	3
	A	13	5
Grangeville sandy loam	F	82	1
	S	78	2
	M	45	3
	A	12	5
Hacienda fine sandy loam	A	3	6
Deep phase	S	61	2
	W	54	3
	M	27	4
	A	7	6
Hacienda loamy sand	W	44	3
	M	22	4
	A	6	6
Deep phase	W	45	3
	M	22	4
	A	5	6
Kettleman-Altamont complex	F	34	4
Kettleman loam	W	15	5
Lethent silty clay loam	W	50	3
	M	16	5
	A	6	6
Hummocky phase	W	42	3
	M	13	5
	A	5	6
Lewis clay loam	W	10	5
	A	2	6
Lost Hills clay loam	F	71	2
	W	67	2
	M	39	4
	A	11	5
Lost Hills fine sandy loam	W	79	2
	M	46	3
	A	12	5
Lost Hills loamy fine sand	W	69	2
	M	40	3
	A	11	5
Merced adobe clay	S	21	4
	W	20	4
	A	3	6
Merced clay loam	S	30	4
	W	28	4
	M	15	5
	A	4	6
Merced loam	M	16	5

TABLE 5.—*Ratings of soils in Kings County, Calif.*—Continued

Soil type	Alkali concentration [1]	Rating	Grade
Merced silty clay loam, shallow phase (over Lethent soil material)	S	55	3
	M	15	5
	A	6	6
Nacimiento clay	F	39	4
Panoche clay loam	F	85	1
	W	60	2
	M	43	3
	A	13	5
Panoche fine sandy loam	F	100	1
	W	95	1
	M	60	2
	A	15	5
Beach phase	W	72	2
	M	36	4
	A	14	5
Panoche loam	F	100	1
	W	95	1
	M	60	2
Panoche loamy fine sand	F	81	1
	W	77	2
	M	49	3
Pond loam	A	5	6
Riverwash		2	6
Rossi loam	S	43	3
	M	19	5
	A	5	6
Rough mountainous land		8	6
Temple loam	S	37	3
	W	35	3
	A	4	6
Traver fine sandy loam	S	77	1
	M	34	4
	W	27	4
	M	18	5
	A	9	6
Traver loam	S	75	2
	M	33	4
	A	8	6
Tulare clay	W	40	3
	M	20	4
	A	5	6
Tulare clay loam	W	52	3
	M	26	4
	A	7	6
Tulare fine sand	W	34	4
	M	17	5
	A	4	6
Beach phase	M	8	6
	A	2	6
Tulare fine sandy loam	W	51	3
	M	26	4
	A	7	6
Tulare loam	W	61	2
	M	31	4
	A	8	6

[1] F=free of alkali; S=spotted; W=weak concentrations; M=moderate concentrations; A=strong concentrations.

MORPHOLOGY AND GENESIS OF SOILS

Soil is the product of the forces of weathering and soil development acting on the soil materials deposited or accumulated by geologic agencies. The characteristics of the soil at any given point depend on (1) the physical and mineralogical composition of the parent soil material; (2) the climate under which the soil material has accumulated and existed since accumulation; (3) the plant and animal life in and on the soil; (4) the relief, or lay of the land; and (5) the length of time the forces of soil development have acted on the soil material. External climate is less important in its effects on soil development than internal soil climate, which depends not only on

temperature, rainfall, and humidity, but on the physical characteristics of the soil or soil material and the relief. The relief, in turn, strongly influences drainage, aeration, runoff, erosion, and exposure to sun and wind.

The climate of Kings County is distinctly semiarid, with a rainfall between 5 and 10 inches annually. The degree of variation in rainfall occurring over most of the county is not sufficient to give rise to differences in soil development; rather these differences are directly or indirectly due to drainage and soil moisture, dominated by waters flowing into the county from the Sierras. Because of relatively flat relief east of the valley axis, a high water table is present during part of the year and some of the soils of the valley basin may be submerged for varying periods. Soils west of the valley axis for the most part have good drainage and are without perennial streams. A grass-shrub vegetation is typical, with the more alkali-tolerant vegetation occurring east of the axis. The mild, wet winters, in which the temperature rarely drops to freezing, produce a luxuriant grass cover, but the hot dry summers promote the rapid oxidation of organic residues in well-drained soils so that they are of relatively low content of organic matter and have a light-brown color. The lower lying poorly drained soils contain greater quantities of decomposed organic matter and are dark gray or nearly black.

The parent material of the soils is of two distinct kinds: All the soils west of the valley axis are developed from materials having their source in sedimentary rocks, largely calcareous sandstones and shales; whereas the soils east of this line have developed from alluvial materials derived mainly from granitic rocks. These soils contain conspicuous particles or flakes of mica, chiefly biotite.

In general the soils are brown, light brown, or brownish gray, except where soil moisture conditions have been such as to produce a dark gray or nearly black color by promoting a more rank vegetative growth and the retention of the decayed organic products. The soils containing large quantities of salts have a gray color. It is difficult to differentiate between the soils that contain sodium carbonate and those that do not. In general, however, the soils containing this salt occur in the eastern part of the county. It should not be construed that the salts of this eastern part are wholly of a sodium carbonate nature, but this salt does occur throughout this area in association with the sulfates and chlorides. Its greatest influence is probably reflected in the development of the Pond, Fresno, Lewis, and Hacienda soils—at least its greatest concentration is found in these soils.

The soils of Kings County are placed in five groups with one group being subdivided on the basis of drainage. The location of these groups is shown in figure 2, page 11. Although these groups admirably present the soils of the county on a land-use basis, they also present a logical classification of the soils on the basis of profile characteristics. According to the principles set forth by Kellogg (*18*) concerning zonal, intrazonal, and azonal soils, it seems apparent that the zonal soils of this region are not represented in this county. The intrazonal and azonal soils, however, are well represented. In substance he defines the zonal soils of a region as having an undulating but not hilly or flat relief, as having good but not excessive drainage, as being somewhat but not strongly eroded, and as having been in place long enough

for the soil-forming processes to have expressed their full significance. The intrazonal soils are more or less well developed, but the soil characteristics show the dominance of such local factors as drainage, relief, or parent material over the forces tending to develop the zonal soils. All but three of the soil series represented in the area belong to this group. The three series of recently accumulated soils, the Grangeville, Foster, and Panoche, belong to the azonal group, which have little or no profile development. Most of the soils of the intrazonal group are developing by the process of salinization and represent different degrees or stages of the Solonchak. The Traver, Pond, Fresno, Lewis, and Hacienda series are the best examples of the alkali (sodium) Solonchaks, whereas the Lethent series represents the alkaline-earth Solonchaks.

Shaw [14] has grouped the soils of California into a classification, the skeleton divisions of which are designated as order, class, division, family, series, and type. If this classification is accepted, one complete family and parts of two other families are believed to be represented in this area. The Fresno family is represented by the Grangeville, Traver, Pond, and Fresno soil series with the Fresno series being the most strongly developed member. The Foster, Chino, and Merced series seem to present the general sequence of the Merced family in this area. Two transitional soil types of the Chino series link these families. Chino fine sandy loam is the transitional type between the Foster and Chino series, whereas the Merced and Chino series are linked by Chino clay. The Lost Hills and the Panoche soils are also obviously closely related. In the other soil series mapped the family relations are not obvious or only one member is present.

The Kettleman, Altamont, and Nacimiento soils comprise the soils of the foothill areas. These soils have developed in place from calcareous sandstones and shales under a short grass cover and with an annual rainfall of about 6 to 8 inches. The hills for the most part represent abrupt, steep, geologic anticlines with a gradient of 40 percent in many places. The normal erosion is severe on these steeper slopes, and the softly consolidated bedrock is frequently exposed; thus the depth of the soil profiles ranges from 10 to 40 inches, and because of the relief a normal profile is not to be expected.

A description of a representative profile of Kettleman loam is as follows: The grayish-brown loam surface soil is 12 inches thick and is soft with little definite structure. The 2-inch surface layer is granular and loose. Many worm and root channels penetrate this highly calcareous layer. The subsoil has a thickness of 22 inches and grades into bedrock 34 inches below the surface. This light grayish-brown soft granular subsoil layer contains some white segregated lime and gypsum in root holes. It has a very smooth clay loam texture and fewer worm holes and casts than are present in the surface soil. The substratum, or parent bedrock, is a much-fractured fine-grained gray and brown shale. The sides of the fragments contain slight accumulations of lime, but the fresh-broken shale is noncalcareous. An irregular transitional zone about 5 inches thick exists between the subsoil and this shaly parent material.

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[14] SHAW, C. F. SOME CALIFORNIA SOILS AND THEIR RELATIONSHIPS. Univ. Calif. Syllabus Series, Syllabus J. D., 117 pp., 1937. [Processed.]

The Nacimiento soil has a brown or dark-brown surface soil and a more compact, dense, and well-developed subsoil containing more accumulated lime than does that of the Kettleman soils; otherwise the two soil series resemble each other. The Nacimiento soil apparently receives more moisture, supports a more vigorous growth of grasses, and has a darker color.

Soils of the recent alluvial fans and flood plains consist of the Panoche, Grangeville, Foster, and Dinuba soil series. They have a smooth flood plain or river fan relief with good surface and internal drainage except where a high water table interferes. The parent material of the Panoche soils is derived from sedimentary rocks. The Panoche soils support a moderate cover of short grasses, but the content of organic matter is very low because of low rainfall and the oxidizing effect of the hot dry summers. They are recent, loose, calcareous soils and are receiving surface deposition from the eroding Kettleman soils. There is little differentiation of soil horizons, as is indicated by the following description of Panoche loam taken from a pit in the NE¼SW¼ sec. 28, T. 22 S., R. 17 E. The loose, soft, weak-granular grayish-brown surface soil is slightly calcareous. The texture is a loam containing much sand, but the fine material is surprisingly sticky if worked when wet. Many small fibrous grass roots permeate the layer. The subsoil, lying below 10 inches, is slightly firmer than the surface soil and breaks into a soft lumpy condition. Fewer roots are present, and the material has a more pronounced gray cast than does the surface soil. It is highly calcareous, and occasionally faint lime coatings line old root channels. The horizon continues downward without a marked change in character except for variations due to stratification.

The Grangeville soils of the Kings River fan are derived mainly from transported alluvium from granitic rocks. The grass cover includes a large percentage of the salt-tolerant grasses, and near the larger streams are scattered valley oaks. These soils have been considerably influenced by a high water table; they are light-textured and are found on the upper or higher parts of the river fan. The recent nature of this soil is indicated by the following description from a profile of the fine sandy loam type in the SE¼ sec. 16, T. 19 S., R. 21 E. The loose structureless fine sandy loam surface soil has a rather dark-brown color when moist, but a pronounced gray cast when the soil is dry. It contains a noticeable quantity of organic matter that is also less conspicuous when dry. The 10-inch light-brown subsoil contains mottlings of a deep rust-brown color. It is soft and structureless and has a fine sandy loam texture. The light-brown color grades with depth into a gray, in which the mottling is more pronounced. Below a depth of 32 inches the texture is a loamy fine sand, and in the deeper material the differences in texture are due to stratification. The soil is calcareous throughout and contains a large quantity of biotite mica. Roots penetrate as deep as 72 inches.

The Foster soils have a dark-gray surface color that results from the decay and retention of organic matter. They have a slight depressional relief and are imperfectly to poorly drained. The greater quantity of moisture results in a heavier vegetative cover than is

found on the Grangeville soils. The Foster soils have a tendency to occur farther out than the Grangeville on the flatter part of the river fan, but the two occur together to some extent. These two soils are almost identical in all respects except for the darker color of the surface soils of the Foster soils and their more mottled subsoil, a condition brought about by low position and excess moisture.

Because of unusually deep surface soils, the Dinuba series is perhaps not quite typical of the Dinuba soil as previously recognized.

The soils of the old alluvial fans and valley plains usually are found on the outer fringes of the fans or in slight depressional areas. They fall into two subdivisions on the basis of drainage—well-drained and poorly drained.

The Commatti and Lost Hills series represent the well-drained subgroup. These soils are characterized by their comparatively high position on sloping alluvial fans. The parent material is of sedimentary-rock origin. A short-grass cover flourishes during the moist season but dries quickly with the approach of summer. Lost Hills fine sandy loam is representative of this group, and the profile here described was observed in the NE¼NE¼ sec. 35, T. 24 S., R. 19 E.:

A. 0 to 16 inches, grayish-brown fine sandy loam. Little structure or only soft easily crushed lumps occur. Soil is slightly calcareous, and many fine grass roots are present. The content of organic matter is low.

B_1. 16 to 28 inches, light-brown fine sandy loam of almost plastic consistence and very hard when dry. Upper part of layer is encountered abruptly. This layer is dense and has no structure except for a few cracks penetrating 3 inches into the upper part. Small well-preserved root holes permeate the calcareous mass.

B_2. 28 to 43 inches, light-brown fine sandy clay loam layer masked to some extent by the large quantity of white segregated lime, which fills holes and cracks. Rich-brown colloidal stains are found along the few cracks and seams. When disturbed, the material breaks into small clods, but little apparent structure exists in the undisturbed soil mass. Quite hard when dry.

C. 43 to 60 inches, loose structureless light-gray calcareous sand containing fragments of shale and gravel.

The surface soils in the Commatti series are brown. The subsoils are less dense and compact than in the Lost Hills soils, although they are slightly developed and contain segregated lime.

The poorly drained subgroup of the old alluvial fans and valley plains is represented by the Chino series, dark-gray soils; the Lethent series, grayish-brown soils; and the Traver, Pond, Fresno, and Lewis series, light-gray soils. All show variable degrees of profile development under the influence of poor drainage, and all support a grass-shrub cover composed largely of alkali-tolerant plants.

A representative profile of Chino loam in the SW¼SW¼ sec. 18, T. 19 S., R. 23 E. presents the following characteristics:

A. 0 to 8 inches, dark-gray highly calcareous loam with a soft lumpy or granular structure. A large quantity of organic matter is present.

B_1. 8 to 22 inches, very dark-gray clay, noticeably darker than surface soil. Small white specks and lines of segregated lime occur, especially in lower part. It has a distinct blocky structure with aggregates ½ to 1 inch in diameter that separate readily and are quite firm.

B_2. 22 to 48 inches, white segregated lime tends to mask dark grayish-brown clay loam, the brown shade increasing with depth. Blocks are slightly larger and less stable and separate less easily than in the B_1 layer.

C. 48 to 60 inches, light-brown hard and compact loam with no distinct structure, calcareous in upper part but only faintly so at 60 inches.

The Chino soils occur on the outer margin of the river fans where moisture conditions have permitted a good growth of grasses and weeds. The high water table, poor surface drainage, and moderate concentrations of salts have markedly influenced their development.

The Lethent soils have developed from alluvium derived from sedimentary rocks under the influence of poor drainage resulting from the flat relief and an extremely dense heavy-textured substratum. They contain strong concentrations of salts, largely calcium, sodium, and magnesium sulfates, but no sodium carbonate. The high salt content and the dense subsoils have played a most prominent part in their development.

The sequence of profile development displayed by the Traver, Pond, and Fresno soil series is quite evident, and in this region the Grangeville appears to be the youngest member of the family according to Shaw.[15] The exact chemical process involved can as yet only be a matter of speculation, but they have developed from transported parent material mainly of granitic origin in the presence of calcium and sodium carbonate, with other salts, and under the influence of excess moisture resulting from a flat poorly drained surface and a high water table. The Fresno hardpan is highly calcareous but will not entirely break down when placed in acid. Traver fine sandy loam is here described from a pit in the NW¼NE¼ sec. 25, T. 20 S., R. 22 E.

A. 0 to 7 inches, light brownish-gray structureless soft and friable fine sandy loam, the topmost 2 inches slightly dry and hard. In most places the upper ¼ inch is vesicular. The material is highly calcareous. Surface soil rests abruptly on subsoil horizon.
B. 7 to 16 inches, brown massive hard or compact fine sandy loam. The few cracks or root holes that occur are coated with a thin almost metallic-appearing colloidal material. This layer seems to indicate that a part has been mechanically deposited.
C. 16 to 60 inches, light-brown loose structureless and highly calcareous fine sandy loam. At 34 inches a loamy sand layer is encountered that is due to stratification, which is typical of the substratum.

Both the Fresno and Pond soils as mapped are believed to be more strongly developed than is generally considered typical. Some difference in the character of the hardpan horizon occurs between the Fresno soils lying east and those lying west and north of Cross Creek. The hardpan in the latter areas lies deeper, is not so hard although quite dense and impervious, has a bluish-gray color, and seems to be less closely related to the surface horizon; whereas the hardpan in the areas east of the creek is definitely related to the present surface soil, has a dull or brownish-gray color, and has a metallic ring when struck with a pick.

The Merced, Rossi, Temple, Tulare, and Hacienda soil series are classified as soils of the valley basin and as such they are subject to overflow, though much less frequently than formerly. The Tulare and Merced once supported a vigorous vegetative cover and as a result have dark-colored surface soils, whereas the Hacienda soils surround

[15] See footnote 13, p. 82.

the old lake margin, where a high alkali content and insufficient moisture result in a thin grass cover and consequently a lighter color. Of these soils the Merced have the strongest profile development. The profile of Merced clay loam described here was observed in the NE¼ SE¼ sec. 34, T. 24 S., R. 21 E.

A. 0 to 6 inches, very dark brownish-gray clay loam with a well-developed soft small granular or soft-lumpy structure. It is strongly calcareous and contains very large quantities of organic matter.

B_1. 6 to 28 inches, black clay of irregular prismatic structure. The prisms are 3 to 5 inches in diameter and 8 inches long, but are unstable, as they break to irregular hard blocks or clods under moderate pressure. Specks and veins of lime accumulations occur in lower part.

B_2. 28 to 48 inches, dark-gray loam of very hard consistence and distinct small prisms having vertical and horizontal dimensions of about 2 and 1 inches, respectively. A white cast is added by the large quantities of segregated lime.

C. 48 to 72 inches, olive-gray fine sandy loam that dries to a very light-gray color and has a firm consistence and no structure. It is calcareous, and sodium carbonate is present. Many hard small white nodules of lime carbonate occur.

The Hacienda soils exhibit a well-developed prismatic structure in the B_1 horizon. There is doubt, however, whether this structure is a soil development or an incidental character developed upon a heavy-textured subsoil layer and a shallow fine sandy loam or loamy sand surface soil. The soil moisture is removed by the summer heat, and the heavy-textured subsoil cracks open. The surface soil then fills up these cracks, thus creating a cleavage zone that becomes more permanent with each season. This structure is absent in areas having a surface soil deeper than 12 or 15 inches. The subsoil contains strong concentrations of sodium carbonate.

Tulare clay is representative of the Tulare series and is one of the most important soil types of the county. The following profile was observed in SW¼ sec. 10, T. 22 S., R. 21 E.

A. 0 to 22 inches, dark-gray silty clay loam with a soft well-developed cloddy or irregular blocky structure. The 6-inch surface layer consists of a loose soft calcareous granular mulch, containing fragments of shell.

B. 22 to 46 inches, greenish-gray calcareous clay, with faint rust-brown mottlings in the lower part. A fine blocky structure exists; the blocks are ½ to 1 inch in diameter and are slightly firm, although they separate readily.

C. 46 to 60 inches, lead-gray clay with a thin platy structure. The surface of the plates has mottlings of a bright-brown color, and plates are ½ inch thick when removed from the layer but continue to shear off into thinner sections. Many fragments of shell are present.

LABORATORY STUDIES [16]

All soil samples for laboratory analyses were screened through a 2-millimeter sieve. The aggregates were crushed with a rubber-tipped pestle, and the gravel and stones larger than 2 millimeters were rubbed relatively clean. The sieved material was thoroughly mixed and aliquot parts were used for the laboratory analysis.

[16] This section contributed by E. P. Perry, division of soil technology, University of California.

MECHANICAL ANALYSES

A mechanical analysis was made of each surface soil sample by the proximate method—a weighed sample of the sieved soil was shaken overnight in distilled water to which ammonia had been added as a dispersing agent. The sand was separated from the silt and clay by wet sieving through a 300-mesh sieve, was dried, weighed, and reported as total sand separate. The suspension of silt and clay that passed through the sieve was made up to one liter, allowed to stand, and sampled by pipette at proper depths and time intervals to give effective maximum diameters of silt at 50 microns, and clay at 5 microns. These results are used only to check the field textural classification.

For a more complete study, samples were chosen from a number of soils, including representative soils of the east side of the valley, the poorly drained soils of the valley trough, the alluvial fan soils of the west side, and a soil from the hills on the west side.

Mechanical analyses of these soil samples were made by the modified International method in which a weighed sample of the sieved soil was pretreated with hydrogen peroxide and hydrochloric acid to remove, respectively, organic matter and carbonates. After washing free of electrolytes, dispersal was effected by shaking overnight with distilled water to which sodium oxalate had been added. The sand was separated from the silt and clay by wet sieving through a 300-mesh sieve, dried, sieved, and weighed to determine the percentages of the different grades of sands. The suspension of silt and clay was sampled by pipette at proper depths and time intervals to give effective maximum diameters of silt at 50 microns, coarse clay at 5 microns, fine clay at 2 microns, and colloidal clay at 1 micron. The results of these analyses are given in table 6.

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TABLE 6.—*Mechanical analyses [1] of samples of 9 soils from Kings County, Calif.*

Soil type and sample No.	Depth	Fine gravel (2 mm.–1 mm.)	Coarse sand (1 mm.–0.5 mm.)	Medium sand (0.5 mm.–0.25 mm.)	Fine sand (0.25 mm.–0.10 mm.)	Very fine sand (0.10 mm.–0.05 mm.)	Silt (50μ–5μ)	Coarse clay (5μ–2μ)	Fine clay [2] (2μ)	Colloidal clay	Total
	Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Grangeville fine sandy loam:											
579133	0–10	0.6	3.3	1.6	29.0	25.1	31.7	3.2	5.8	2.9	100.3
579134	10–32	.2	1.3	1.1	27.1	33.5	29.9	2.2	4.7	3.0	100.0
579135	32–62	.1	1.0	1.4	38.5	34.6	18.7	2.1	4.0	3.0	100.4
579136	62–72	(3)	.4	2.0	56.0	28.2	9.9	.5	3.0	2.5	100.0
Lethent silty clay loam:											
579140	0–8	------	(3)	.1	1.0	5.5	58.3	6.0	29.3	16.3	100.2
579141	8–24	------	------	(3)	.5	3.3	38.3	26.6	31.4	16.4	100.1
579142	24–43	------	(3)	(3)	.7	2.8	32.3	17.4	48.1	37.2	101.3
579143	43–72	------	------	.1	1.3	3.2	41.1	13.7	41.0	31.0	100.4
Merced clay loam:											
579144	0–6	(3)	.1	.3	1.8	4.9	50.9	15.8	27.1	15.2	100.8
579145	6–28	(3)	.2	.6	2.8	3.1	37.9	9.3	46.7	39.5	100.6
579146	28–48	.1	1.7	5.4	24.4	12.4	37.9	2.6	17.4	12.7	101.9
579147	48–72	.3	1.6	3.2	43.0	25.6	23.1	1.2	2.5	2.0	100.5
Fresno fine sandy loam:											
579148	0–7	.4	5.4	8.5	26.5	17.0	33.8	3.4	5.3	4.0	100.3
579149	7–15	.8	6.4	8.5	24.8	10.9	31.2	4.4	12.9	9.2	99.9
579150	15–45	.3	3.4	5.5	28.8	20.4	35.0	2.7	3.4	2.6	99.5
579151	45–72	.9	5.7	9.3	20.6	8.8	40.8	8.2	6.5	3.4	100.8
Pond loam:											
579184	0–6	.7	5.1	7.4	17.0	8.9	41.0	7.5	11.5	5.0	99.1
579185	6–14	.9	7.1	9.8	18.7	9.5	31.8	9.3	13.1	6.7	100.2
579186	14–42	1.8	13.7	15.0	24.5	9.5	24.0	6.5	5.6	3.8	100.6
579187	42–54	.6	4.7	6.1	18.1	14.4	44.4	7.6	4.8	2.7	100.7
Traver fine sandy loam:											
579188	0–7	.8	7.2	16.8	38.3	10.5	19.0	1.8	5.6	3.2	100.0
579189	7–16	.7	8.4	18.4	39.1	10.0	17.7	2.3	3.9	1.8	100.5
579190	16–34	1.1	7.5	18.9	41.7	10.9	15.9	2.2	2.3	1.9	100.5
579191	34–72	3.6	11.3	8.6	30.5	14.0	23.7	3.4	4.2	2.9	99.3
Lost Hills fine sandy loam:											
5791103	0–16	.6	7.9	25.0	30.6	10.0	11.2	1.6	13.7	10.8	100.6
5791104	16–28	.5	6.2	25.9	32.5	8.6	8.7	1.5	16.9	13.1	100.8
5791105	28–43	.6	7.3	22.8	28.6	9.9	21.7	3.2	6.3	4.0	100.4
5791106	43–60	.7	9.9	42.2	35.4	4.0	5.1	.4	2.8	2.5	100.5
Kettleman loam:											
5791110	0–14	1.3	4.7	11.2	25.9	15.9	26.3	5.1	10.3	5.8	100.7
5791111	14–26	3.5	8.2	22.9	34.0	12.1	14.7	1.6	3.9	3.4	100.9
5791112	26–40	12.3	15.0	11.0	21.4	13.3	18.5	2.9	5.9	4.9	100.3
Panoche clay loam:											
5791113	0–14	.3	1.5	4.1	16.6	16.7	46.4	7.7	7.0	3.1	100.3
5791114	14–45	.1	.8	2.0	8.9	6.7	46.0	12.1	23.5	16.9	100.1
5791115	45–72	.3	.9	2.5	12.3	10.5	42.1	10.6	21.5	15.5	100.7

[1] Modified International method.
[2] Includes also colloidal clay.
[3] Trace.

MOISTURE EQUIVALENTS

Moisture equivalents were determined by the standard method, in which 30 grams of saturated soil are subjected to a force of 1,000 times gravity in a centrifuge, results being reported as the percentage of moisture by weight calculated on the oven-dry basis. They represent approximately the normal field-moisture capacity, or the quantity of water that is held in a soil after a heavy rain or an irrigation where drainage downward is free and uninterrupted. The results are shown in table 7, together with pH values, and do not deviate from the usual for the textures among the soils examined.

TABLE 7.—*Determinations of moisture equivalents, carbonates,*[1] *and pH values*[2] *in soils of Kings County, Calif.*

Soil type and sample number	Depth	Moisture equivalent	Carbonates	pH
	Inches	*Percent*	*Percent*	
Tulare clay:				
579101	0–20	46.32	19.5	8.2
579102	20–35	53.36	22.6	8.0
579103	35–60	57.44	18.0	7.8
Tulare clay loam:				
579107	0–26	[3] 45.38	18.9	8.4
579108	26–32	50.77	4.4	7.9
579109	32–60	[3] 38.77	2.2	7.9
Tulare loam:				
579110	0–8	[3] 27.91	14.6	8.3
579111	8–24	[3] 57.80	10.9	9.0
579112	24–36	[3] 67.74	2.4	9.0
579113	36–44	[4] 87.27	2.2	8.6
579114	44–57	[4] 86.57	1.9	8.5
579115	57–68	[3] 52.89	2.8	8.1
Tulare fine sandy loam:				
579116	0–18	16.01	8.3	8.8
579117	18–29	43.95	4.1	8.4
579118	29–52	[3,4] 52.04	5.4	8.4
579119	52–60	[3,4] 46.70	3.3	8.7
Hacienda fine sandy loam:				
579120	0–8	6.14	6.6	7.9
579121	8–16	24.88	15.0	9.2
579122	16–31	[3,4] 38.96	8.1	9.1
579123	31–46	[3,4] 42.54	21.3	8.7
579124	46–60	[3] 19.15	6.3	8.9
Dinuba sandy loam:				
579125	0–14	12.34	.7	7.5
579126	14–41	11.70	2.6	8.8
579127	41–54	16.36	12.9	9.3
579128	54–60	10.69	2.7	9.3
579129	60–72	20.33	2.3	8.8
Grangeville loamy fine sand:				
579130	0–19	7.31	.8	7.7
579131	19–36	5.36	.2	9.0
579132	36–72	6.11	.5	9.3
Grangeville fine sandy loam:				
579133	0–10	15.71	1.2	9.2
579134	10–32	13.26	.8	7.0
579135	32–62	9.58	.6	8.6
579136	62–72	5.85	.3	7.8
Grangeville sandy loam:				
579137	0–7	9.64	.4	7.1
579138	7–41	8.42	.6	8.9
579139	41–67	7.29	1.9	9.1
Lethent silty clay loam:				
579140	0–8	32.53	4.9	8.4
579141	8–24	[3] 37.18	5.9	8.2
579142	24–43	[3] 48.90	4.6	8.1
579143	43–72	[3,4] 46.27	4.6	7.9
Merced clay loam:				
579144	0–6	36.37	9.8	7.5
579145	6–28	[3] 40.07	13.7	8.5
579146	28–48	[3] 27.12	22.5	9.2
579147	48–72	27.15	11.7	9.7
Fresno fine sandy loam:				
579148	0–7	14.56	5.2	7.7
579149	7–15	[3] 27.95	4.9	9.4
579150	15–45	16.15	15.5	9.6
579151	45–72	22.08	3.4	8.0

See footnotes at end of table.

TABLE 7.—*Determinations of moisture equivalents, carbonates,*[1] *and pH values*[2] *in soils of Kings County, Calif.*—Continued

Soil type and sample number	Depth	Moisture equivalent	Carbonates	pH
Lewis clay loam:	*Inches*	*Percent*	*Percent*	
579152	0–5	26.55	7.2	9.5
579153	5–12	[3] 44.06	2.5	10.0
579154	12–37	[3] 67.63	7.8	10.1
579155	37–60	27.21	18.7	9.8
579156	60–72	10.25	2.0	9.6
Rossi loam:				
579161	0–4	23.60	2.6	7.5
579162	4–14	[3] 29.88	9.5	9.4
579163	14–38	27.59	8.8	9.9
579164	38–53	[3 4] 29.81	3.5	10.0
579165	53–72	10.48	2.5	9.7
Merced adobe clay:				
579166	0–16	55.00	8.5	8.5
579167	16–32	[3] 51.50	12.0	8.1
579168	32–67	[3] 53.77	12.6	8.6
579169	67–72	[3] 31.14	.9	8.0
Foster loam:				
579170	0–18	24.65	1.5	8.2
579171	18–38	21.32	.9	7.4
579172	38–72	20.25	.9	7.9
Chino clay:				
579176	0–16	[3] 41.85	2.9	7.3
579177	16–39	[3] 58.70	6.8	9.3
579178	39–58	35.41	6.6	9.5
579179	58–72	[3] 17.12	1.6	9.3
Chino clay loam:				
579180	0–9	29.43	3.4	8.3
579181	9–31	30.50	4.5	8.7
579182	31–49	25.01	13.1	8.7
579183	49–72	18.93	4.4	8.1
Pond loam:				
579184	0–6	24.47	9.5	9.3
579185	6–14	21.28	13.8	9.9
579186	14–42	20.25	13.5	9.9
579187	42–54	20.01	14.1	9.4
Traver fine sandy loam:				
579188	0–7	11.60	5.0	9.6
579189	7–16	14.55	5.2	10.3
579190	16–34	11.85	4.7	10.5
579191	34–72	21.58	10.7	10.5
Chino fine sandy loam:				
579192	0–8	17.73	.7	7.8
579193	8–21	18.89	.8	8.1
579194	21–41	14.07	.9	8.1
579195	41–60	26.74	10.1	8.5
Chino loam:				
579196	0–8	27.31	3.1	8.3
579197	8–22	29.88	14.0	9.2
579198	22–48	23.45	12.9	8.7
579199	48–60	20.30	.9	8.0
Panoche fine sandy loam:				
5791100	0–15	13.18	.8	7.8
5791101	15–37	16.32	5.2	8.4
5791102	37–60	15.52	3.1	8.7
Lost Hills fine sandy loam:				
5791103	0–16	11.12	1.9	7.8
5791104	16–28	15.91	2.1	8.8
5791105	28–43	23.57	5.7	8.6
5791106	43–60	5.47	.8	8.5
Kettleman loam:				
5791110	0–14	18.66	2.0	8.0
5791111	14–26	21.46	6.3	8.6
5791112	26–40	([5])	25.8	8.2
Panoche clay loam:				
5791113	0–14	21.67	3.9	8.4
5791114	14–45	26.12	4.0	8.5
5791115	45–72	23.43	3.3	8.6
Panoche loam:				
5791116	0–10	17.46	1.2	7.7
5791117	10–40	19.04	4.2	8.4
5791118	40–72	17.79	4.7	8.6
Nacimiento clay:				
5791122	0–10	30.30	3.9	8.2
5791123	10–34	29.62	10.1	8.4
5791124	34–48	([5])	----------	----------

See footnote at end of table.

TABLE 7.—*Determinations of moisture equivalents, carbonates,*[1] *and pH values*[2] *in soils of Kings County, Calif.*—Continued

Soil type and sample number	Depth	Moisture equivalent	Carbonates	pH
Foster clay loam:	*Inches*	*Percent*	*Percent*	
5791128	0–11	25.09	13.3	9.4
5791129	11–23	28.10	8.5	8.2
5791130	23–72	20.91	.6	7.2
Foster fine sandy loam:				
5791131	0–13	15.06	.7	6.8
5791132	13–34	8.40	.5	6.8
5791133	34–60	2.57	.3	7.5
Commatti clay loam:				
5791134	0–15	25.22	1.4	7.6
5791135	15–34	25.85	5.4	8.4
5791136	34–70	26.64	7.2	9.2

[1] By the McMiller method.
[2] Determinations made by the glass-electrode method, using a 1:2 suspension.
[3] Determinations made by using waxed paper liners in centrifuge boxes to permit the escape of water.
[4] Water was standing on top of the soil after the centrifuging.
[5] Shale.
[6] Bedrock.

CARBONATES

Carbonates were determined on all the soils by the McMiller method, in which the soil is treated with standard hydrochloric acid until effervescence ceases and then is titrated back with standard base to determine the quantity of acid that is used in the reaction, calculating it as the equivalent quantity of calcium carbonate. It is recognized that this method involves certain errors, particularly when sodium carbonate is present, since the total carbonate is calculated as calcium carbonate, or lime.

REACTION

Determinations of the pH of these soils were made by the Beckman pH meter using 1:2 suspensions of soil and water.

DISCUSSION

In general the soils on the east side of the area fall into the coarser textural groups, because of their origin from granitic materials. Those in the troughs, near the center of the area, are very low in sand content, as the sand grains have been deposited farther up on the alluvial fans. The soils of the west-side fans tend to be low in clay content, with textures very similar to the soils of the hills on the extreme west side of the area (the Kettleman series).

The Tulare soils occur on the very gently sloping bed of Tulare Lake. They tend to be high in silt and low in sand content. Tulare clay contains a very high content of total clay (76 percent $<5\mu$) as well as a high content of colloidal clay (34 percent $<1\mu$). On drying, this soil cracks into a blocky or adobe structure.

Tulare clay loam, although similarly very low in sand, contains more silt and less clay and does not exhibit this marked cracking on drying.

Other clay soils in the area are relatively high in silt and low in sand and tend to have more mellowness than is usually associated with the clay texture. This is due not only to the relatively high silt content

but also to the presence of calcium ions from gypsum and lime, which are present in most of the soils of the west side and of the valley trough.

In this region of low rainfall the soils are not subject to intensive leaching, and nearly all of them have pH values above 7. The most acid soil sample tested is from the surface layer of Foster fine sandy loam, with a pH of 6.8; the most basic is from the subsoil of Traver fine sandy loam, with a pH of 10.5. Many of the soils of this region are calcareous. The semicemented conglomerate on which the shallow phase of Commatti clay loam has developed contains 45 percent $CaCO_3$. The shale on which the Kettleman soils have developed contains 26 percent. The subsoils of Tulare clay, Tulare clay loam, Hacienda fine sandy loam, and Merced clay loam each contains more than 20 percent of lime. In addition to the lime many of the soils contain black alkali and many contain gypsum.

The moisture equivalent values tend to be high in the soils of the valley trough, especially in the subsoil samples. The presence of sodium carbonate tends to make many of these soils impermeable, so that the centrifugal force is not sufficient to throw the water out of the soil. These samples, which have water standing on the top of the soil after centrifuging, are rerun with waxed paper linings around the sides of the moisture equivalent cups, thus keeping drainage channels open around the edges. These high values therefore should not be interpreted as signifying an excellent water-holding capacity for agricultural use, but signifying, instead, deflocculated and impermeable horizons.

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Office of the Assistant Secretary for Civil Rights
1400 Independence Avenue, SW
Washington, D.C. 20250-9410;

(2) fax: (202) 690-7442; or

(3) email: program.intake@usda.gov.

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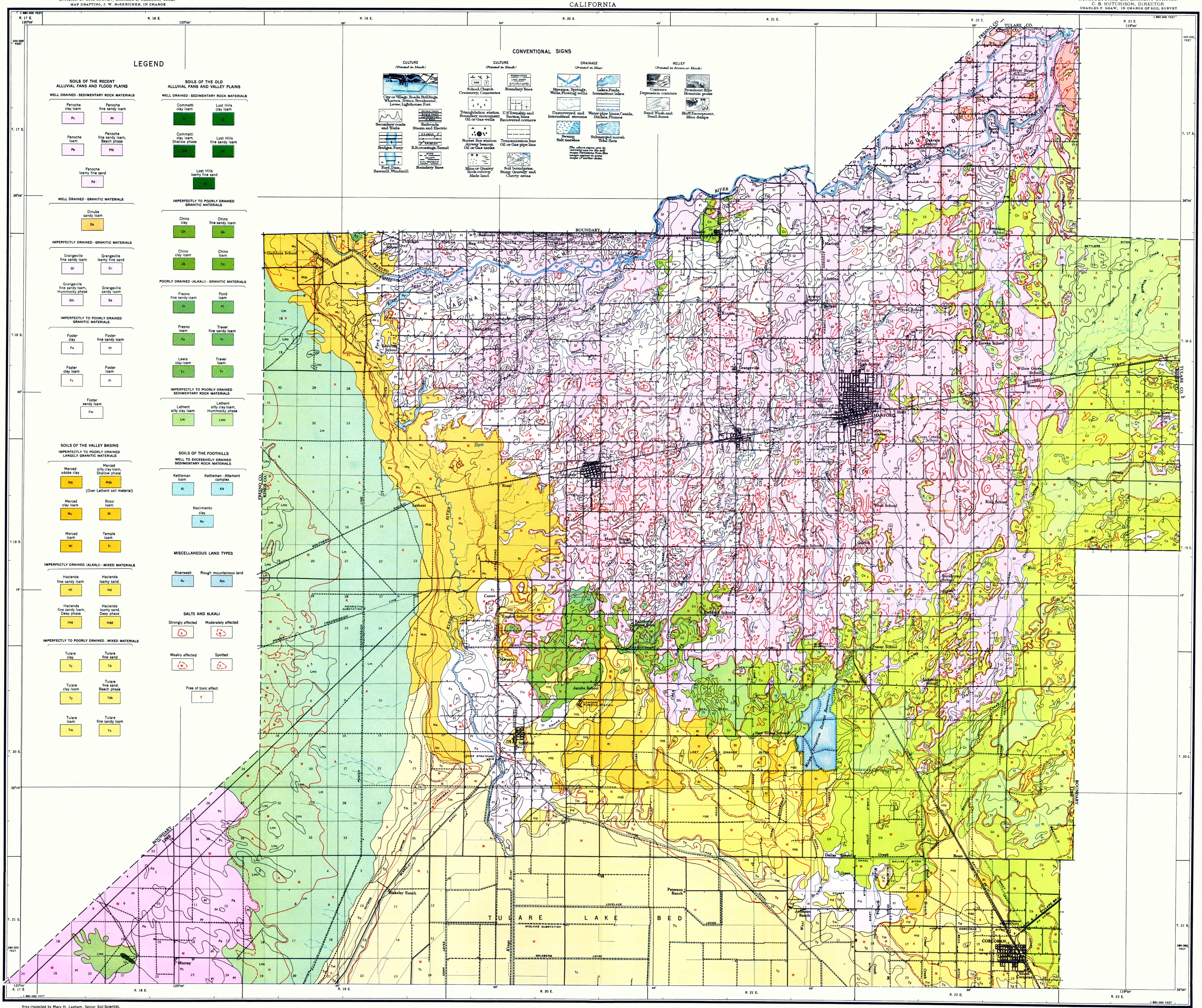
AGRICULTURAL RESEARCH ADMINISTRATION
BUREAU OF PLANT INDUSTRY, SOILS, AND AGRICULTURAL ENGINEERING
ROBERT M. SALTER, CHIEF
DIVISION OF SOIL SURVEY, CHARLES E. KELLOGG, CHIEF
MAP DRAFTING, J. W. McKERICHER, IN CHARGE

SOIL MAP

KINGS COUNTY – NORTHERN SHEET

CALIFORNIA

UNIVERSITY OF CALIFORNIA
AGRICULTURAL EXPERIMENT STATION
C. B. HUTCHISON, DIRECTOR
CHARLES F. SHAW, IN CHARGE OF SOIL SURVEY



Area inspected by Macy H. Lapham, Senior Soil Scientist.
Soils surveyed by John L. Retzer, U. S. Department of Agriculture, in charge, and R. A. Gardner, L. F. Koehler, and Ralph C. Cole, University of California.

Scale 1 inch = 1 mile

Polyconic projection, 1927 North American datum.
Base map from U. S. Geological Survey Sheets.
10 000 foot grid based upon California (Zone 4) system of plane coordinates.
Surveyed in 1937-38. Series 1938

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MAP DRAFTING, J. W. Mc KERICHER, IN CHARGE

SOIL MAP

KINGS COUNTY—SOUTHERN SHEET

CALIFORNIA

UNIVERSITY OF CALIFORNIA
AGRICULTURAL EXPERIMENT STATION
C. B. HUTCHISON, DIRECTOR
CHARLES F. SHAW, IN CHARGE OF SOIL SURVEY

LEGEND

SOILS OF THE RECENT ALLUVIAL FANS AND FLOOD PLAINS

WELL DRAINED - SEDIMENTARY ROCK MATERIALS

- Panoche clay loam — Pc
- Panoche fine sandy loam — Pf
- Panoche loam — Pa
- Panoche fine sandy loam, Beach phase — Pfb
- Panoche loamy fine sand — Pd

WELL DRAINED - GRANITIC MATERIALS

- Dinuba sandy loam — Ds

IMPERFECTLY DRAINED - GRANITIC MATERIALS

- Grangeville fine sandy loam — Gf
- Grangeville loamy fine sand — Gl
- Grangeville fine sandy loam, Hummocky phase — Gfc
- Grangeville sandy loam — Gs

IMPERFECTLY TO POORLY DRAINED GRANITIC MATERIALS

- Foster clay — Fo
- Foster fine sandy loam — Ff
- Foster clay loam — Fc
- Foster loam — Fl
- Foster sandy loam — Fm

SOILS OF THE VALLEY BASINS

IMPERFECTLY TO POORLY DRAINED LARGELY GRANITIC MATERIALS

- Merced adobe clay — Ma
- Merced silty clay loam, Shallow phase — Mds (Over Lethent soil material)
- Merced clay loam — Mc
- Rossi loam — Rl
- Merced loam — Ml
- Temple loam — Tl

IMPERFECTLY DRAINED (ALKALI) - MIXED MATERIALS

- Hacienda fine sandy loam — Hf
- Hacienda loamy sand — Hd
- Hacienda fine sandy loam, Deep phase — Hfd
- Hacienda loamy sand, Deep phase — Hdd

IMPERFECTLY TO POORLY DRAINED - MIXED MATERIALS

- Tulare clay — Tc
- Tulare fine sand — Td
- Tulare clay loam — Ty
- Tulare fine sand, Beach phase — Tdb
- Tulare loam — Tm
- Tulare fine sandy loam — Tu

SOILS OF THE OLD ALLUVIAL FANS AND VALLEY PLAINS

WELL DRAINED - SEDIMENTARY ROCK MATERIALS

- Commatti clay loam — Cl
- Lost Hills clay loam — Ll
- Commatti clay loam, Shallow phase — Cls
- Lost Hills fine sandy loam — Ls
- Lost Hills loamy fine sand — Lf

IMPERFECTLY TO POORLY DRAINED GRANITIC MATERIALS

- Chino clay — Ch
- Chino fine sandy loam — Cs
- Chino clay loam — Cc
- Chino loam — Cn

POORLY DRAINED (ALKALI) - GRANITIC MATERIALS

- Fresno fine sandy loam — Fr
- Pond loam — Pl
- Fresno loam — Fs
- Traver fine sandy loam — Tf
- Lewis clay loam — Lc
- Traver loam — Tr

IMPERFECTLY TO POORLY DRAINED SEDIMENTARY ROCK MATERIALS

- Lethent silty clay loam — Lm
- Lethent silty clay loam, Hummocky phase — Lmc

SOILS OF THE FOOTHILLS

WELL TO EXCESSIVELY DRAINED SEDIMENTARY ROCK MATERIALS

- Kettleman loam — Kl
- Kettleman - Altamont complex — KA
- Nacimiento clay — Nc

MISCELLANEOUS LAND TYPES

- Riverwash — Rv
- Rough mountainous land — Rm

SALTS AND ALKALI

- Strongly affected — A
- Moderately affected — M
- Weakly affected — W
- Spotted — S
- Free of toxic effect — F

Area inspected by Macy H. Lapham, Senior Soil Scientist.
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1 ½ 0 1 2 3 4 Miles

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